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YDROMORPHISM OF SOILS

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The problem of classifying soils, including ydromorphic" soils, in the chernozem and estnut soil zones was studied at a plenary ssion of the interdepartmental commission soil classification held in February, 1958. became clear in the course of discussion that e proposed project on classification did not flect precisely enough a) the special fea- res of the excessive moisture of "hydromor- ic soils — both of sub-soil and surface soil; d b) the related peculiarities of the genesis these soils.

The term "hydromorphic soils" was suggested Neustruyev. He wrote (8, p. 40): "Soils rmed in such conditions (in level and well- ained positions at higher elevations are some- nes called zonal soils. But we prefer to give em another name. We suggest that it would correct to call them automorphic soils, to stinguish them from hydromorphic soils, or ils that are excessively wet (for the zone ncerned)." Later, on page 147, Neustruyev ites: "The process of bog formation can be nveniently broken down into a number of other, ore elementary processes... These processes n be preferably grouped as 'hydromorphic' ocesses. Excessive moisture (seasonal or nstant) produces two alternative consequences. can bring about a capillary rise of solutions th precipitates in the upper soil horizons of e substances raised by evaporation or altered ncentration (and also by lateral flow). Or it n cause an anaerobic condition in the soil ass, preventing oxygen from reaching its ganic and mineral substances. Thus the ncept of excessive moisture becomes concrete d its effects become easy to detect in nature. e capillary and excess-capillary (gravitation-) water in these soils can of course be estab- shed by many years of observation of their ter regime."

From these quotations it is apparent that ustruyev was really linking the term "hydro- orphic" with the idea of increased soil mois- re, without differentiating between its causes, t pointing out that increased moisture can be accompanied by either salinization or the appearance in the soil of anaerobic conditions.

These phenomena, however, are genetically extremely varied; they differ also as regards the way in which the soil moisture behaves.

First, let us agree on certain terms.

Soil wetting is the term we shall use to describe the process of moisture entering the soil regardless of where it comes from. The term normal wetting will refer to cases when the moisture enters the soil only in the form of atmospheric precipitations, and in quantities not exceeding a total characteristic for the climate of the locality. Correspondingly, the term increased wetting will refer to cases when the soil receives some quantity of moisture over and above what is normal, for example, from surface flow in low-lying areas or as a result of moisture from allochthonous ground waters penetrating the soil stratum.

The term soil moisture will, according to accepted practice, be used to mean the soil moisture content. Here we propose to describe moisture that does not exceed the minimum moisture capacity as normal. Moisture that does exceed this factor[1] we shall describe as increased moisture.

The choice of the minimum moisture capacity (MMC) as the factor differentiating between normal and increased moisture has been made for several reasons.[2]

---

[1] Clearly these definitions of "normal" and "increased" moistening and "normal" and "increased" moisture are applicable for any zone.

[2] By the minimum moisture capacity MMC of a soil stratum we mean the minimum quantity of suspended moisture that can be retained in a motionless or quasi-motionless state by forces inherent in that particular stratum.

e abrupt change in soil moisture orresponds to this value. Moisture present in soil above the MMC value can move quickly in any direction, including upwards.

Second, when the soil moisture (not including sandy soils) exceeds the MMC value the air penetrability and oxygen regime deteriorate and reducing processes begin.

Third, as moisture passes through the MMC value, the mechanism of moisture-retention changes. When moisture does not exceed the MMC value the water is retained in each elementary soil stratum by forces inherent in that stratum itself (suspended moisture). When the moisture content is higher, however, retention of water in the soil is always attended by properties characteristic of the lower-lying strata (perched moisture, and perched — suspended moisture).

Both additional wetting and increased moisture influence the soil formation process considerably — but in different ways. As we shall see, increased moisture can arise both as a result of additional wetting and without it. Moreover, when additional wetting is present the moisture can be both normal and increased. In other words, additional wetting and increased moisture are not necessarily concomitant phenomena.

First, let us consider the problem of soil moisture with normal wetting. The moisture regime here depends wholly upon the structure of the soil stratum.

Here there can be three different cases.

First: the soil stratum is homogeneous to a great depth, i. e, it is not stratified, and is sufficiently permeable to water. Ground waters lie at a depth of several meters (10 and more). In this case, in steppe and more arid zone conditions with normal precipitations, at times when wetting is at its maximum, thawed water soaks into the soil to a few meters (1-4) depth and is retained in the form of sorbed "suspended" (9) waters, bringing the moisture of the saturated soil layer to the minimum moisture capacity (MMC). During the growing season all the moisture which has entered the soil is used by the vegetation, and the soil dries out to the wilting moisture (WM). Water regimes of this type, accompanied by a normal moisture regime, are of the non-leaching variety and are characteristic of the present steppe chernozems, chestnut soils, grey earths, and others.

Deep lying soil waters are characteristic also of the second case. But in this case the soil and soil material layers are not homogeneous: its upper, fine-porous (and usually finer-texture) alluvium is underlaid at a few meters' depth — in the lower part of the soil profile or just a little lower than its lower boundary — by a coarse, porous (usually coars textured) alluvium.

Lebedev (7) was the first to show that in soils of this kind a certain additional accumulation of moisture (compared with MMC) occurs above the boundary of changed alluvium after intense saturation of the upper alluvium. He called this sort of moisture "capillary-suspended, " and also explained how it was retained.

Staprens (11), developing Lebedev's thesis, established experimentally 1) that the distribution of capillary-suspended moisture in the upper alluvium corresponds to the upper segment of the capillary curve characteristic of this alluvium; 2) that the thickness of a stratum containing capillary-suspended moisture is equal to the difference between the maximu height of capillary rise characteristics of the upper and lower alluvium; and 3) that capillar suspended moisture in the upper alluvium at the same time possesses the properties of "capillary-perched" water (Kachinskiy's term) and is able in particular to flow laterally, abov the alluvium boundary when a hydraulic gradient is present.[3]

It follows from Lebedev's and Staprens' theses that the form of humidity under study possesses the properties of both "suspended" and "sustained" humidity at the same time. Since other forms of suspended humidity are encountered in soils, we propose to call this form capillary perched-suspended-moisture.

The distribution of moisture in a two-layere soil of this type after influx of excessive gravitational water is shown in Figure 1 by a continuous heavy line. The horizontal arrows show th minimum moisture capacity values (MMC_1 and MMC_2 for the upper and lower alluvia, respectively), i. e., those MMC values that are characteristic of these alluvia separately, provided each of them is underlain by a thick homogeneous stratum. The thickness of the upper alluvium is denoted by the symbol N, and the maximum possible thickness of a stratum containing capillary perched-suspende moisture by the symbol n. This stratum can be designated the suspension horizon. Its thic ness, according to Staprens (11), is equal to the difference between the maximum heights o capillary rise of the upper and lower alluvia.

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[3] Let us note that Staprens studied the properties of perched and suspended moisture in sandy soils of varying coarseness. We are applying the laws he established to clay loam texture, possessing microstructure. This undoubtedly requires experimental confirmation.

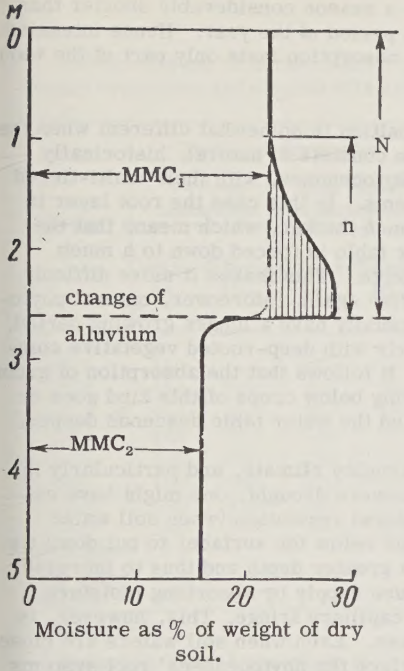

Fig. 1. - Distribution of moisture in a two-layered soil after influx of excessive gravitational water.

e hatched area in Figure 1 denotes the
ximum amount of perched-suspended mois-
re that can be retained in the upper alluvium
er and above its own particular MMC$_1$ value.
he upper alluvium were not underlain by
ower and larger-porous alluvium, this
isture — other things being equal — would
ve flowed down beyond the limits of the soil
ratum. It follows that even when wetting is
rmal the two-layered stratum creates in-
eased moisture and thereby increases the
ailability of moisture for plants moreover,
additionally retained quantity of moisture
ssesses great mobility and therefore a high
gree of availability as far as plants are
ncerned.

This quantity depends of course on the
ckness of the upper alluvium (reaching a
ximum when $n \leqslant N$) and on the difference
tween the upper and lower alluvia's texture
more precisely, the difference between
size of their pores). The greater this
ference, the greater is the amount of perched
ispended moisture that can accumulate in
upper alluvium. This quantity can attain
ignificant value. Thus, Bol'shakov and
anas'yeva observed (perched communica-
n) in the Central Black Soil Preserve in
rsk region, where the upper, finer-textured,
ss-like clay loam is underlain at a depth of
)-220 cm by a coarser-textured layer, that
quantity of moisture additionally retained
can amount to 80-100 mm.

It should be emphasized that the two-layered structure of the soil is by no means rare. On the contrary it is widespread. Thus, Afanas'yeva (personal communication) and Firsova (12) observed that the two-layered loess-like clay loam soils — identical with that in the Central Chernozem Preserve, and having an extraordinarily constant upper thick alluvium — are widespread within the northern and central parts of the Central-Russian high elevations. Afanas'yeva (2) observed two-layered deposits showing the same correlation of alluvia in western Siberia.

It is clear from the foregoing that the importance of this phenomenon and its influence upon moisture supplies for plants must not be underestimated.

In the third case the soil stratum is also not homogeneous; but in this case the relative disposition of the strata is reversed: below the coarse-textured alluvium lies a finer-textured one, impervious to water. Moisture infiltrating as a result of precipitation penetrates to it and, accumulating in the form of perched water, forms a water-bearing horizon of autochthonous ground waters. As a result of the infiltration of precipitation the capillary fringe of these waters, ane even their water table, can occur periodically in the lower part of the soil stratum, i. e., in the soil layer where roots occur. Let us recall that we are at present examining different cases where wetting is normal: this excludes the possibility of allochonous soil waters, which could be a source of additional wetting, participating in the soil water regime.

Ground waters lying close to the surface in the steppe zone are often to be observed not only in low-lying relief elements (e. g., terraces), where they are largely allochthonous, but also on watersheds (both level and, sometimes, dissected), where they are undoubtedly autochthonous. We have observed them on the flattened plateau in Zaporozh'ye (Orlansk district), where the waters were found at a depth of about three meters. The presence of ground waters lying close to the surface in the Kamennaya Steppe is common knowledge. For example, in the "virgin steppe" sector, we observed them in 1951 at a depth of four meters. With regard to the dissected watershed plateau, we observed a shallow depth of ground waters in the eastern part of the Central-Russian eminence, in the Tim and Sosna basins. Afanas'yeva (personal communication) observed this phenomenon on the Kalachayev high elevation and also in the area between the Buzuluk and Khopr Rivers (in the Annenskaya MTS district), etc. Numerous cases of ground waters lying close to the surface in steppe zone watersheds can easily be found in

Garmonov's map (4).

The idea of constant autochthonous ground waters existing close to the surface in the steppe zone presents one difficulty which requires elucidation.

In the steppe zone, as is known, the wetting coefficient is lower than one, i. e, the evaporation exceeds precipitation. Proceeding from this and bearing in mind Alpat'yev's rule (1) whereby the vegetative cover, given adequate soil moisture, uses moisture in quantities roughly approximating the evaporation, we should conclude that autochthonous ground waters, being one of the forms of accumulation in the soil of moisture from atmospheric precipitations, are unable to exist for any reasonably lengthy period in steppe zone conditions. With their high mobility and, consequently, availability for vegetation, they ought to be quickly used. inasmuch as vegetation fully absorbs from the soil all the moisture resulting from atmospheric precipitations. Moreover ground waters can also disappear as a result of seepage.

These considerations force us to establish the conditions under which autochthonous ground waters in the steppe zone can, nevertheless, and actually do, exist.

The first and perhaps most important of these conditions is the limited extent to which they are absorbed by vegetation. According to Alpat'yev's rule, these waters are absorbed intensively by vegetation only so long as its roots penetrate the capillary fringe, even if only its upper part. As soon as a stratum containing moisture below the minimum moisture capacity appears between the upper boundary of the capillary fringe and the lower boundary of the root zone, then the intensiveness of the soil waters' absorption slows down; and if the moisture in this stratum falls to such an extent that rupture of the capillary link occurs, then absorption sinks practically to nil. Let us recall that where there are maximum and minimum moisture capacities characteristic of soils in loess-like strata and corresponding to approximately 40% and 30% of the volume, a 10-mm moisture absorption entails a 10-cm reduction in the ground-water level and consequently of the upper boundary of the capillary fringe. Thus even a comparatively small moisture absorption can sever the upper boundary of the capillary fringe from the lower boundary of the root-bearing stratum, after which the absorption of ground waters becomes mineral. This is of particular importance when the vegetation concerned is agricultural crops. The roots of the majority of annual crops penetrate no deeper than two meters. With a capillary fringe thickness of, say, two meters, this entails the ground-water table being forced down to a depth of not more than four meters. Moreover, many annual crops have by no means a lengthy growing season — a season considerably shorter than the warm period of the year. Hence intensive moisture absorption lasts only part of the warm season.

The position is somewhat different when the vegetation consists of natural, historically formed phytocenoses, with their multi-tiered root systems. In this case the root layer is usually much thicker, which means that the soil water table is forced down to a much greater depth. This makes it more difficult for it to rise again. Moreover, natural phytocenoses usually have a longer growing period, particularly with deep-rooted vegetative components. It follows that the absorption of groun waters lying below crops of this kind goes on longer, and the water table descends deeper.

In a droughty climate, and particularly in years of severe drought, one might have expected natural vegetation (when soil water lies not far below the surface) to put down its roots to a greater depth and thus to increase its moisture supply by absorbing moisture from the capillary fringe. This, however, is not the case. Even when soil waters are close to the surface the phytocenoses' root systems seem possessed of a certain "conservatism" as it were: they grow downwards only as far as a definite limit, depending upon the biological characteristics of the species concerned.

Let us illustrate what has just been said by an example. Table 1 shows data denoting the drying of dark colored soil in depressions with natural grass phytocenosis and an artificial tre plantation (a tripe-row strip of small-leafed elm and Russian olive). These data refer to the northwestern part of the Caspian lowland, which is distinguished by ideal qualities of general levelness and clearly expressed microrelief. Elements of the latter are small depressions, microelevations and the microslope which interconnect them. The difference in height between the depressions and microelevations does not exceed 30-40 cm. The depressions receive additional moisture (for further details, see Rode [10]) from their greater accumulation of snow and from melted water flowing down from the microelevations. As a result nearly every year the soils below the depressions are saturated by melted water, of which the excess drains down into the ground waters lying generally at a depth of some six meters. The capillary fringe thickness is three meters. The depressions are covered with different types of grass vegetation, the main components of which (6) are:

Species	Root Penetration Depth, (cm)
Koeleria	120
Festuca Sulcata	130
Euagropyrum	150
Stipa	210
Alfalfa and other grasses	300

Table 1

Autumn drying of dark-colored chernozem-like soil of a depression under natural grassy vegetation and planted with a triple-row strip of small-leafed elm and Russian olive[a]

Year	Depth of drying to				Autumn deficit of moisture in stratum, dried to MMC (mm)		Autumn depth of ground waters, (cm)		Total precipitation in hydrological years, (mm)		
	wetting moisture		min. moist. capacity(cm)						Cold	Warm	Year
	Grasses	Plantation	Grasses	Plantation	Grasses	Plantation	Grasses	Plantation	Half-year		
1951	150	—	330	—	316	—	650	660	101	66	167
1952	110	180	290	290	249	253	580	—	185	186	371
1953	110	250	330	330	244	312	560	—	166	99	265
1954	150	320	330	390	273	362	600	—	60	191	251
1955	150	380	330	420	314	419	610	690	124	78	202
1956	160	380	330	420	321	408	600	670	108	177	285
1957	160	360	300	450	261	409	580	670	182	69	241
1958	—	390	—	430	—	404	—	—	—	—	—
Average for many years	—	—	—	—	—	—	—	—	126	154	280

---

[a] Materials from Dzhanybek station of Forest Institute of Academy of Science, USSR.

From Table 1 we see that the thickness of e fully-dried stratum, i. e., the stratum om which the available moisture has been lly absorbed, varies from 110 cm in wet ears to 160 cm in dry. At the same time e thickness of the whole horizon of drying . e., of the stratum, at the same time the ickness of the whole horizon of drying (i. e., the stratum, at the lower boundary of which oisture equals the MMC) remains extra-rdinarily constant, amounting to 330 cm; ly in exceptionally wet years, such as 1952 d it diminish to 290 cm. The vegetation of e depressions abosrbed a total of not more an 450 mm of moisture during the growing ason, and in dry years the figure was only 0-350 mm, i. e., only about half the evapor-ion which is a little over 800 mm for the owing season. Had they extended their roots eper, the plants would have been able to ob-in more moisture. However, even in such ry dry years as 1951, 1955, and 1957, no ch extension of roots was observed, and e constancy of the thickness of the whole rizon of drying testifies to this. This justi-es our reference to the "conservatism" of the ot systems of the phytocenosis concerned. it if we replace the natural phytocenosis by mething else, for example, by tree strip, en the picture immediately changes. Table 1 ows parallel data for the same soil, but anted to a triple-row strip of Russian olive d elm. This was established in 1951 and grew pidly. We see that over the first five years e thickness of the stratum of thorough drying d the thickness of the whole horizon of drying and also the autumn moisture deficit all quickly rose, and then became stable (this stabilization may not yet be final). All the figures referring to the plantation are considerably greater than those for the grass phytocenosis: the thickness of the stratum of thorough drying is 360-390 cm instead of 110-160; the general thickness of the horizon of drying is 420-450 cm instead of 330; the moisture deficit is 400-420 mm instead of 240-320; and the depth of ground water is 70-90 cm more.

It follows that each phytocenosis on this particular soil has its own corresponding drying regime and its own ground-water level. The latter is determined by the fact that within the limits of the root-layer all the highly mobile moisture, i. e., all the moisture over and above the MMC, is absorbed. Owing to this, by autumn (or even earlier) the upper boundary of the capillary fringe combines with the lower boundary of the root layer. Since the moisture in the capillary fringe is hydrostatically balanced by the ground-water table it turns out that the depth of the latter, where there is no outflow of the ground waters (as is the case in this part of the Caspian lowland), is also regulated by the activity of plants. There is a definite maximum depth below which the level does not descend, since the moisture discharge by desorption cases. On reaching the ground-water level at this depth the capillary fringe breaks away from the root layer, and the discharge of moisture from the fringe and from the water-bearing horizon falls sharply. This depth is roughly equal to the sum of the thicknesses of the root layer and the capillary fringe: in the example under review the figures are 3 + 3 = 6 m.

A second factor enabling autochthonous ground-waters to exist in arid zones is, of course, the possible replenishment of their reserves. What is conducive to this?

We shall hardly be in error if we point out first of all that some sort of microrelief is necessary, through the depressions of which the ground-waters can be fed. Indeed, the infiltration of water into the soil of a site with a level surface must take place evenly, with the result that a saturated stratum of a certain thickness containing "suspended" moisture comes into being. This moisture will in time be dispersed by desorption and evaporation. A water regime of the non leaching type will occur, and there will be replenishment of ground-waters. Only when there are depressions of some form or another on the surface can the quantity of moisture infiltrating in these depressions (usual during snow thaws) exceed that of the autumn residual moisture deficit and ensure penetration and saturation, and consequently the replenishment of ground-waters. In other words, disproportionate infiltration, giving rise to a pot hole regime in the territory concerned, is necessary over a wide area. The importance of a regime of this kind in the feeding of steppe zone ground waters was established by Izmail'skiy (5) and Vysotskiy (3). It was the latter who coined the term "pothole" (nourisher). In the case which concerns us, the essential features of potholes which help to create and maintain a ground-water table close to the diurnal surface are as follows. First, the total volume and surface of the potholes and the mutual disposition of them and of their water-bearing microbasins must be such as to prevent moisture loss by means of general drainage from the area. Second, the depth of the potholes must be great enough to ensure that the amount of moisture accumulating in them suffices to offset the autumn moisture deficit in the soil below them and permit the percolation of some of its surplus into the ground waters.

In pothole territory its soil inevitably becomes complex, for soils in potholes will always be more leached than those areas which lie between potholes. The composition of the complex and the number of components forming it can be extremely varied, depending upon its bioclimatic zone, vegetative cover, microrelief characteristics, presence or absence of salts in the soil stratum, their composition, etc. The Caspian lowland, to which the foregoing example refers, is situated in the subzone of light-chestnut soils. Its complex is composed of dark-colored chernozem-like soils of depressions, light-chestnut soils of microslopes, and solonchak solonetz of microelevations. Strictly speaking, ground waters are autochthonous only below depressions, for it is only from under depressions that they find their way under microelevations: the gradual dispersion of the domes of these waters formed under depressions in the spring testifies to this. It is because of this that ground-waters under microelevations appear to be allochthonous. But we must regard this whole complex, in which individual components are interconnected, as an entity; owing to this, the ground-waters situated beneath them, despite their own complexity, are nonetheless autochonous.

Territorial potholes which create uneven infiltration are particularly significant in the context of the relatively evenly porportioned pattern of annual precipitations which is, for example, characteristic of the European part o the USSR. Potholes become relatively less important when total precipitations are large and their annual pattern uneven: but these factors can be offset to a certain extent by the precipitations infiltrating disproportionately into the soil. For example, in the USSR's eastern regions, typified by monsoon-type precipitations which become very much more concentrated in July and August, the wetting coefficient is higher than one. Consequently, in this area we can expect a continuous infiltration of precipitations (their surplus over evaporation) over the entire territory, with a corresponding effect upon the feeding of groun waters. Here, too, of course, territorial potholes will tend to increase the feeding of groun waters, although it plays no decisive part in the processes by which the feeding originally begins to take place.

Another factor which might help to replenish the reserve of ground-waters is the shallow depth to their level and, consequently, the sma moisture deficit in the stratum above their water table — a deficit which must be made good before the precipitations begin to percolate: and without this percolation process of course, replenishment of the ground-waters cannot take place. As we have seen, the quantity of the deficit and the depth to which the soil stratum becomes thoroughly dried out depend upon the composition of the vegetation.

Periodicity in the volume of precipitation also has an important effect. In particular, periods of several years, in which the volume of precipitation is higher than the average total help to replenish the ground-water supply at that time.

The important factor is climatic conditions. In regions where the wetting coefficient approaches one, autochthonous waters are forme far more easily than where it is much less tha one. Regular winter thaws are of great importance: they help the winter precipitations to infiltrate, making their loss by evaporation or w removal less likely. The soil texture is also most important. The coarser textured and, ence, the more permeable it is, and the less s the moisture capacity and the height of the apillary rise, the more easily the soil water re- erve is replenished and the more stable it is. hat is why we find ground waters close to the oil surface in sandy massives situated in re- ions with even a very droughty and semidesert limate.

A third and most important condition govern- ng the existence of ground waters at a shallow epth in the steppe zone is absence of seepage. his factor is helped by the level surface and orizontal disposition of the water barrier. The epth of the latter and the thickness of the water- earing horizon have the following significance. /here there is complete general levelness (for xample, on the Caspian lowland) the depth of the ater barrier is of no particular importance. It an even be very great, in which case only the noisture in the upper layers of the water-bearing orizon participate in the exchange of moisture ith vegetation and atmosphere. The more trongly dissected the relief is, the nearer the ater barrier must be to the surface, so that the urface of the depression of the ground waters an be as close as possible to the horizontal lane: this reduces seepage and brings the water able close to the surface (Fig. 2).

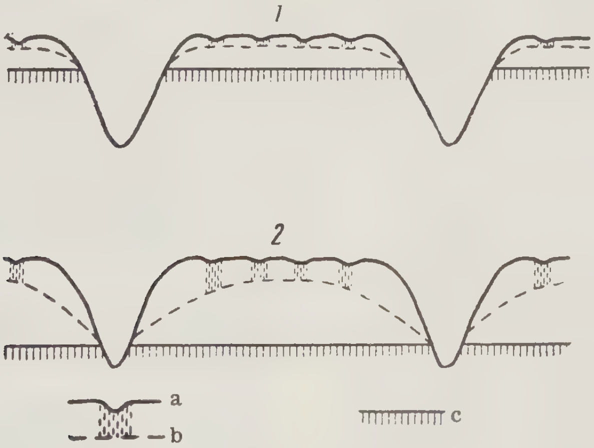

Fig. 2. - Influence of depth of water barrier on character of ground-water table.
1 - Water barrier close to surface; 2 - Lowered position of water barrier. a - Pothole; b - Ground-water table; c - Water barrier.

In conditions where even a slow ground seep- ge occurs, autochthonous waters are unable to orm close to the surface, except in territories here the wetting coefficient (WC)$\gtrless$1.

Now we must decide the question: what, in e light of the foregoing, is the effect of autochthonous ground waters lying "close"[4] to the soil surface upon the water regime of the soils which contain them?

First, the water table of these waters plays the part of a water barrier helping the soil to retain the infiltrated waters from atmospheric precipitations, in the form of perched water, i. e., highly mobile and available. The waters referred to thereby help, on the one hand, to increase the availability of the moisture from atmospheric precipitations; on the other, they help to create in the soil upward flow (mostly capillary) which counteracts all sorts of eluvial phenomena.

Secondly, in years and periods of several years with subnormal precipitations the waters referred to can serve as a reserve of moisture for plants. Situated for the most part, as we have indicated, below the root layer, this moisture is not easily available, for in flowing towards the roots it has to pass through a soil stratum which has poor water-conducting properties. A certain amount of it can be used by plants by absorption into the root layer.

It must be specially emphasized that in the context of periods of several years these waters do not constitute any additional source of moisture for plants, for they represent only one of the forms in which moisture from normal atmospheric precipitations accumulates in the soil. But this form of moisture is the most mobile and consequently possesses high availability for plants — the more so in that it can move easily and in an upward direction as and when the moisture stored in the upper part of the root layer gets used up. An identical quantity of moisture present in soil in the form of perched water in one case, and of suspended moisture (i. e., the form usually encountered in steppe soils) in another, will supply plants better in the first case because of its greater mobility. The depth of root distribution needed to utilize the identical quantities of moisture will be considerably less in the first case. At the same time the perched water can be more easily lost by evaporation or soil seepage.

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[4] The word "close" is understood to mean ground waters whose capillary fringe would be periodically in the upper soil layer.

From all that has been said above we see that the moisture in soil can increase even under normal wetting conditions. The cause of this increased moisture is the nonhomogeneous parent material from which the soil has formed, entailing an accumulation of perched-suspended or perched water.

Let us turn now to the question of the effect of additional wetting upon soil moisture.

Additional soil wetting can come about in three main ways: 1) as a result of the inflow of atmospheric precipitations where the soil is situated in a depression; 2) as a result of the surface accumulation of additional quantities of snow blown up against some obstacle, with ensuing infiltration of thawed water into the soil; 3) as a result of allochthonous ground waters entering the soil.

In the first and second cases the additional quantity of precipitation cannot by itself bring about increased moisture, for where the soil is homogeneous and the ground waters deep the additional moisture infiltrates into the soil, increasing only the wetting depth and moisture storage as compared with the same soil without the additional wetting. When the extent of the latter is considerable it can bring about saturation, thereby altering a nonleaching type water regime into leaching type, i. e., bringing about a substantial qualitative change in the soil formation process. However, the soil moisture cannot exceed the MMC in this case either, i. e., it remains normal.

Nonhomogeneity of the soil is, as we have seen, the cause of increased moisture. Additional surface wetting can intensify this phenomenon. However, with a soil structural profile conditioning the accumulation of perched-suspended moisture, the effect of additional surface wetting cannot be considerable because, as we have seen, the amount of perched-suspended moisture accumulating is definitely limited. On the contrary, with a soil structural profile conditioning the appearance of a water-bearing horizon close to the surface, the additional surface wetting will have the effect of increasing the horizon's thickness and raising the ground-water table and of the upper boundary of the capillary fringe, i. e., it will directly help to bring about increased moisture.

In the third case, when allochthonous soil waters create additional wetting, they can exer a dual effect upon soil moisture. If they lie at a depth where their capillary fringe only comes near the soil profile's lower boundary, they play the part of a sort of water barrier, sustaining the moisture percolating from atmospheric precipitations, even when these are normal in quantity, and thereby promoting increased moisture. This moisture, closing up with the capillary fringe, raises the latter's upper boundary and the ground-water table. If the allochthonous waters' capillary fringe, and, even more so, their water table, enter into the soil profile, then they increase the soil's moisture directly. In both cases it is the allochthonous waters which are the cause of the increas moisture in the soil.

What, then, in the light of all that has been said, must we call "hydromorphic" soils?

We would suggest that the concept of hydromorphism be linked exclusively with increased moisture of soils. In other words, we suggest that the term hydromorphic soils be given to those in whose soil profile (throughout the whol profile or only in any part of it) moisture exceeding that of the MMC is observed over a more or less lengthy period (i. e., not only during the period necessary for the percolating gravitational moisture to seep down). This moisture can be formed from perched water (i. e., capillary fringe of autochthonous or allochthonous waters) or from perched-suspended water.

The causes of hydromorphism can be a stratified soil profile and additional wetting of the soil from allochthonous ground waters.

Hydromorphism manifests itself most stron ly and clearly where it is conditioned by the appearance in the soil profile of perched water associated with the influx of allochthonous ground waters, which lend the hydromorphism particular stability.

Autochthonous ground waters usually denote a lesser degree of hydromorphism. If their capillary fringe penetrates the soil profile only for a short time such soils cannot rightly be called hydromorphic.

The accumulation in the soil of perched-suspended moisture also entails hydromorphism, but less stable and not so clearly defined. It i the weaker in this case, the more similar as regards pore sizes the upper and lower alluvia

Table 2

enetical characteristics of soils of steppe and more arid zones depending upon soil structural profile and wetting conditions

haracter of additional wetting	Soil structural profile and position of ground waters		
	Homogeneous structural profile	Two-layered structural profile	Homogeneous or two-layered structural profile
	Deep ground waters		Ground waters close to surface
dditional wetting not present	Normal wetting Normal moisture Non-leaching-type water regime "Zonal" soil	Normal wetting Increased moisture from accumulation of perched suspended moisture Non-leaching-type water regime "Zonal" soil with increased moisture or meadow-zonal soil	Normal wetting Moisture in dry years normal; in wet years increased by perched water of capillary fringe Autochthonous ground waters Type of water regime: dry years, nonleaching; wet years, desorption-seepage Soil: zonal with increased moisture of meadow-zonal
rface	Increased wetting Normal moisture Periodic leaching-type water regime "Zonal" leached soil, or "zonal" soil distinctive of neighboring moisture bioclimatic zone or sub-zone, or soil with special properties also more or less leached	Increased wetting Increased moisture from accumulation of perched suspended moisture Periodic leaching-type water regime "Zonal" leached (or even podzolized) soil with increased moisture or meadow-zonal soil	Increased wetting Increased moisture Ground-soil waters autochthonous Periodic leaching-type water regime Leached meadow-zonal or zonal-meadow soil
ith allochthonous soil waters	—	—	Increased wetting Increased moisture from perched water of capillary fringe or water-bearing horizon Ground-soil waters allochthonous Water-regime type desorption-seepage or seepage Soils: zonal-meadow (more rarely meadow-zonal) — zolonetz-like, solonchak, or saline.

re, and the greater the difference between the ickness of the upper alluvium and the thickness the suspended horizon, i. e., the deeper the tter is.

We would suggest that the degree of soil hyromorphism be defined on the basis of the thickness of that part of the soil profile which has a regime of increased moisture. If this regime embraces the whole profile, then the soils should be called properly hydromorphic; but if it embraces only the lower half of the soil profile, then such soils should be called semihydromorphic.

Additional surface wetting unaccompanied by increased moisture does not entail soil hydromorphism. But it increases the moisture storage in the soil and its leaching and leads to the formation either of "zonal" soil (distinctive of the neighboring moisture zone or subzone), or of soil of a particular type formed under vegetation which is richer than is distinctive of the zone concerned and which has a greater moisture store.

In this connection it might be possible to define more precisely the concept of "meadowness." I have in mind a wordroot used widely in soil nomenclature, namely meadow [lug]. This root is applied either as a prefix or as the basic part of a term, for example "meadow-chernozem" soil or "chernozem-meadow" soil.

We would suggest that the term "meadowness" be used to mean the phenomenon of increased soil moisture where this is accompanied by a predominantly upward rather than downward progression of the capillary fringe in the soil profile or at least in its lower part during the vegetative season. These conditions are in fact ensured by the presence of the soil waters' capillary fringe in the soil profile. Its prolonged presence throughout the whole profile can be regarded as a characteristic sign of "meadow" soils (with some prefix or another); and its presence in the lower half of the profile, as a sign that the prefix "meadow" can be attached to the name of the soil. The latter, lesser degree of "meadowness" can also be formed by perched-suspended moisture, provided it accumulates in quantities large enough to ensure its presence in the soil profile throughout the vegetative season. Clearly, meadow soils will be hydromorphic, and soils with the prefix "meadow" semihydromorphic.

Additional surface wetting cannot by itself cause "meadowness."

It follows from what has been said that the contrasting of automorphic (zonal) soils and hydromorphic soils, which lies at the basis of Neustruyev's proposals, is not completely justified. Soils with a zonal underbase (in the geomorphological sense of the word, i. e., situated on plateau) can be hydromorphic if autochthonous ground waters form in them, or if a perched-suspended moisture accumulates in them. In this case the automorphism of the soils — in the sense of there being no lateral additive of any substances whatsoever — conjoins with their hydromorphism, i. e., increased moisture.

In conclusion attention is drawn to Table 2, which shows different instances of the formati of "zonal," "meadow-zonal" and "zonal-meado soils in steppe and more arid zones in connect with wetting conditions and the soil structural profile.

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IEW DATA ON THE FIXATION OF ATMOSPHERIC NITROGEN N THE NODULES OF LEGUMES[1]

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The process whereby atmospheric nitrogen comes fixed in the nodules of legumes has re- ained obscure until recently.

It is beyond dispute that nodule bacteria hizobium) are unable to fix molecular nitro- n while developing outside the higher plant, d that this process is possible only by means symbiosis of the bacteria and the higher ant. This is the conclusion that emerges om the vast quantity of experimental ma- rial presented by Allison (2). Application the isotope method, using the heavy isotope ^{5} in studying the symbiotic fixation of nitro- n, and begun some 15 years ago by Burris, pling, Wahlin and Wilson (5), established at the fixation of molecular nitrogen also kes place in nodules that have been isolated om plants. However, the intensity of nitro- n fixation in isolated nodules of legumes was t high in the majority of cases. In the ex- riments conducted by Machata, Burris and lson (6) only in three percent of all the trials s fixation reliably established.

In the experiments carried out by Zelitch, rris and Wilson (8), and Aprison, Magee d Burris (3), when soybean nodules were aced in an atmosphere of labeled nitrogen mediately after they had been separated om the plant, nitrogen fixation occurred in cases, although its intensity was not high. nce, isolation of nodules from the whole ant, even for very short periods, sharply nits the intensity of nitrogen fixation. This particularly clear from the data given by nd (4). This investigator placed whole young der plants (Alnus glutinosa) and their isolated dules in an atmosphere enriched with isotope ^{5}, and found that the labeled nitrogen content the isolated nodules was several times lower an that in nodules which had not been isolated om the plants.

Thus a study of molecular nitrogen fixation involving the functioning of the entire symbiotic system as a whole and simultaneous application of the isolated nodules method may open up broader possibilities for further progress in establishing how the fixation process works than the use of isolated nodules alone.

The main objective of the research, the basis results of which are set forth in this paper, was to elucidate the following questions: 1) Precise localization of the process of atmospheric nitrogen fixation. Development of the isotope method in recent years has made it possible to establish that this process takes place in the nodules. But the nodules of legumes constitute a complex system which includes hypertrophy of the higher plant's tissue and bacterial cells. Although Rhizobium bacteria are generally supposed to cause molecular nitrogen fixation in nodules, no exact data confirming this has been obtained. 2) The chemical nature of the primary products of symbiotic nitrogen fixation. 3) The intensity of fixation and the speed of distribution of fixed nitrogen from the nodules into other organs of the plants. 4) Nitrogen fixation in the nodules of legumes and the carbohydrate balance.

Research was carried out for the most part with growing plants and to a lesser degree with nodules isolated from plants. The plants used in the experiments were alfalfa, pea, red clover, and yellow lupine which were grown under greenhouse conditions in containers with dimensions of 20 x 20 cm or 17 x 30 cm.

Before sowing, the seeds were inoculated with a pure culture of highly active nodule bacteria which subsequently caused intensive formation of nodules on the roots of the plants.

The soil (limed podzolic clayloam, from the Dolgoprudnaya Agricultural Chemistry Experimental Station) was given optimum amounts of phosphorus and potassium fertilizers, and also boron and molybdenum.

Apart from the author, the following participated the research work: Z.N. Bersenyeva, Ye.G. vshevskaya, V.V. Zertsalov, and G.G. Zhidkikh.

When the atmospheric nitrogen fixation was at its most intensive period (which could be assessed from the sharply increased growth of the plants and by the intensity of their green coloring), the container was placed in a specially equipped, hermetically closed glass chamber of 33.1 liter capacity furnished with the necessary devices for an inlet and outlet. After the chamber had been checked and found fully sealed, between 8 and 10 liters of air were pumped out. Its outlet manifold was then closed and from gas tanks 1.5 liter of CO_2[2] followed by 6.5-8.5 liters of nitrogen gas enriched with isotope N^{15} was introduced. The degree of enrichment of atmosphere nitrogen with N_2^{15} in the chamber varied, according to the different experiments, from 0.72 to 1.52 atom-percent of the surplus atoms of N^{15} (an enrichment of 2.9 to five times as against the natural content of N^{15} in ordinary nitrogen).

The periods of time over which the plants were exposed in the chamber containing N_2^{15} varied from 12 to 90 hours according to the experiment conditions. When the plant's exposure period had elapsed it was immediately removed and analyzed. After weighing, the leaves, stems and roots of the plants were rubbed in a glass mortar and then subjected to a water extraction process. The water extracts were heated on a steam bath. In these conditions complete coagulation of the albumins took place: the latter were then filtered and examined separately from the filtrate which contained only non-albuminous nitrogen compounds. The fractions isolated from the plants were analyzed for the nitrogen content by the Kjeldahl method and its isotope composition was measured on a MS-2 mass-spectrometer.

The method of examining the nodules had to involve complete separation of the Rhizobium bacteria from the cell sap and the nodule tissue. It was found that by delicately crushing the nodules with a glass rod in a porcelain crucible containing water the bacteria could virtually be completely separated from the nodule tissues by filtering the nodules which had been crushed under water through a fine paper filter. The nodule tissue remains on the filter, and the bacteria, together with the water-diluted nodule cell sap, pass through into the filtrate. The latter is filtered for a second time through a bacterial filtrate — a Chamberlain candle, with partial vacuum to accelerate the filtering process. All the bacteria remain on the filter, and the cell sap solution passes through into the filtrate. The filtered bacterial mass is washed with distilled water and is then removed with a rubber-tipped glass rod. Microscopic examination of a bacterial mass isolated in this way ha shown it to be free from any extraneous matter

To separate bacteria from cell sap we have, in our laboratory, recently been using a supercentrifuge of 20,000 rpm with a 12,000 g acceleration. When the bacteria in the water-dilute cell sap is given two centrifugal treatments for some 15 to 20 minutes virtually all the bacteri are deposited on the walls of the centrifuge rot The results of analysis of the nodule bacteria o alfalfa, of the nodules' cell sap and of nodule tissue washed free from bacteria and cell sap are given in Table 1.

Judging by the nitrogen content, about 55% of the total bacteria mass consists of albuminous substances. Characteristic of the bacteria is a comparatively high iron content. It is interesting that molybdenum, thought to play an important part in nitrogen fixation by nodules, is mainly localized in the nodule tissue cell sap: the bacteria contain about 10 times less molybdenum than the cell sap.

Bacteria isolated from nodules, as well as other nodule components, were analysed for total content of nitrogen and its isotope compos tion (Table 2).

Where pea and alfalfa were subjected to the shortest exposure in an atmosphere of N_2^{15} in this series of experiments — 12 hours — label nitrogen was found in very large amounts in th compound of the water-soluble fraction of the nodules and was completely absent in the bacteria. An extremely low enrichment with isotope N^{15}, within the limits of experimental error, was also found for bacteria nitrogen when alfalfa was exposed in an atmosphere of labeled nitrogen for 24 hours. With longer exposures the content of labeled nitrogen in the bacteria tended to rise, but it cannot be compared with the very high quantity for the water-soluble nitrogenous fraction of nodule cell sap. The content of labeled nitrogen in the albumins of washed nodule tissue is also insignificant, but on the average is somewhat higher than in bacteria.

The results of these experiments provide irrefutable proof of the thesis that atmospheric nitrogen fixation in the nodules of legumes takes place not in bacteria, but in the cells of the nodule tissue, which represents regenerated tissue of the higher plant. The bacteria probably secrete some substance influencing the formation of a specific nodule tissue on legume roots which has its appropriate enzyme system by means of which the fixation of molecular nitrogen in the atmosphere occurs. Bacteria itself cannot fix molecular nitrogen. Hitherto no one has been able to observe nitrogen fixation in pure cultures. And if, with certain investigators, nitrogen fixation with bacteria isolated from plants has seemed to

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[2] Carbon dioxide was introduced into chamber to prevent possible lack of CO_2 for carbon nutrition of plants.

Table 1

Chemical composition of nodule bacteria of alfalfa (Rhizobium Meliloti) of the cell sap of nodules and of nodule tissue (pulp) in percentage dry weight

Nodule Components	Total content in nodules of fraction examined	N	P_2O_5	K_2O	CaO	MgO	Mo	Fe	Polysaccharides
Bacteria	18.0	9.54	1.34	0.37	0.57	0.02	0.0034	0.080	9.8
Cell sap (dry residue)	19.2	9.15	1.09	2.6	1.12	0.55	0.0390	0.020	—
Washed nodule tissue	62.8	4.75	0.45	0.15	0.78	0.03	0.0030	0.040	—

Table 2

Labeled nitrogen in nodule bacteria (Rhizobium), in cell sap of nodules and in albumin of nodule tissue of leguminous plants

Experiment No.	Plant	Period of Exposure in N^{15}[a] atmosphere, hr.	Bacteria (Rhizobium)		Cell sap of Nodule Tissue		Nodule Tissue	
			Atom-percent of excess N^{15}	Labeled nitrogenous % of total	Atom-percent of surplus N^{15}	Labeled nitrogen as % of total	Atom-percent of excess N^{15}	Labeled nitrogen as % of total
1	Alfalfa	12	0.00	0.0	0.18	22.4	0.00	0.0
2	Alfalfa	24	0.02	1.7	0.44	38.5	0.06	5.4
3	Alfalfa	48	0.08	7.0	0.43	37.8	0.09	7.8
4	Alfalfa	90	0.07	6.1	0.41	35.8	0.11	9.7
5	Clover	24	0.03	2.6	0.34	30.0	0.04	3.5
6	Pea	12	0.00	0.0	0.40	35.5	0.00	0.0
7	Pea	24	0.01	0.9	0.61	53.7	0.01	0.9
8	Pea	48	0.05	5.3	0.44	38.2	0.05	4.4
9	Lupine	48	0.07	9.7	0.26	36.2	0.07	9.7

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[a] Enrichment of atmosphere nitrogen with isotope N^{15} was as follows: experiment (1) 0.81 atom-percent of surplus N^{15}; experiment (9) 0.72 atom-percent of surplus N^{15}. In all the other experiments it was 1.14 atom-percent of surplus N^{15}.

ve occurred, then this has been merely a atter of contamination or inadequately prese analytical methods. In the first hours of posure of legumes in an atmosphere enriched th N^{15}, labeled nitrogen can be found only in e water-soluble non-albuminous nitrogenous mpounds of the nodules' cell sap.

In order to establish the chemical nature the first products of symbiotic nitrogen fixon it was essential to determine in precisely at compounds the labeled nitrogen first makes appearance. Data emerging from quantitae chromatographic analysis show that asparine constitutes about 50% of the total water luble nitrogen in alfalfa cell sap (1). Accord- to data obtained in our laboratory by Z. N. rseneva and V. M. Makarevich asparagine is also contained in the nodules of clover, pea and lupine in very large quantities (from 25% to 60%). According to data of Sen and Burma (7) large quantities of asparagine are also present in the cell sap of nodules of legumes grown in India, namely: lentil (Lenz esculenta); vetchling (Lathiyrus sativus); chick-pea (Cicer arietinum); and pea (Pisum sativum). Apart from asparagine, various amino acids also form part of the cell sap compound.

To isolate asparagine and various aminoacids the multi-layered rising on circular chromatogram method was used. The various amino acids were identified by means of ninhydrin reaction on several sheets of the multilayered chromatogram. From these sheets the amino acids were lacalized on the chromatogram sheets which had not been treated with ninhydrin. The sections of paper with amino acids localized on them were cut off, the amino acids were rinsed with distilled water and given a second chromatographic cleansing. In the cleansing process there were considerable losses of some of the amino acids. For this reason the absolute emergence of most of the individual amino acids was small, except for asparagine, large quantities of which were present in the material obtained. In order that the material under study should be available in quantities sufficient to ensure the experiment a high degree of precision, it was found that only the asparagine had to be isolated, separately; all the individual amino acids could be grouped in two lots — bicarbonate amino acids (glutaminic and asparaginic acids) and all the other amino acids.

Table 3 shows the results of isotope analysis of these three fractions of the cell sap of nodules of legumes when exposed in an atmosphere of labeled nitrogen for 24 hours.

Table 3

Distribution of labeled nitrogen in asparagine and other amino acids isolated from cell sap of nodules of legumes.

Plant	Atom-percent of excess N^{15}			Labeled nitrogen as % of total nitrogen		
	Asparagine	Bicarbonate amino acids (asparagine + glutaminic)	Other amino acids	Asparagine	Bicarbonate amino acids (asparagine + glutaminic)	Other amino acids
Alfalfa	0.65	0.24	0.27	57.5	21.0	23.8
Clover	0.47	0.16	0.09	41.3	14.0	7.9
Pea	0.71	0.20	0.26	62.0	17.6	23.0

In these experiments the highest enrichment with isotope N^{15} was found in asparagine. In the bicarbonate amino acids and in the mixture of other amino acids the labeled nitrogen content was found to be several times smaller than in asparagine.

The results of these experiments do not coincide with the data obtained by Aprison, Magee and Burris (3). In studying nitrogen fixation in isolated nodules they found that the highest degree of N^{15} isotope enrichment occurred in glutaminic acid, and that in asparagine it was considerably less. This result in the work carried out by Aprison and his colleagues could be an artifact, for in his experiments the nodules were preliminarily ground in 3 N HCl, which should have resulted in saponification of the asparagine.

A number of our other experiments with alfalfa, clover and pea produced data of exact the same type, showing that nitrogen fixed in legume nodules is used first and foremost for asparagine synthesis — not for synthesis of bicarbonate or any other amino acids. And in the compound of asparagine itself it is in the amide group that labeled nitrogen is found in maximum quantities. This can be seen from the values in Table 4.

Thus, in these experiments the content of labeled nitrogen in a slightly-saponified amid fraction of cell sap was between three and seven times more than in all other nitrogenou fractions of the cell sap of alfalfa nodules. Since asparagine is formed in plants as a result of interaction between ammonia and aspa agine acid, and the amide nitrogen of asparagine is simply transformed ammonia, it follows that it is ammonia alone that is one of th primary, if not the very first product of the biological fixation of atmosphere nitrogen in the nodules of legumes.

Fixed nitrogen in nodules constantly passe into the other plant organs. This process is very rapid. Table 5 shows the experimental results in which the content of labeled nitrogen was determined in different fractions of the cell sap of alfalfa and clover nodules afte exposure of these plants first in an N_2^{15} atmos phere and then for periods of 24 and 48 hours after the N^{15} atmosphere had been replaced b the ordinary, normal atmosphere.

Twenty-four hours after the labeled atmos phere had been replaced by the normal one there was already a sharp fall in the labeled nitrogen content of the nodule cell sap. This

Table 4

Content of labeled nitrogen in slightly saponified amide and unsaponified amine fractions of cell sap of nodules of legumes.

Plant	Duration of exposure in atmosphere of N_2^{15}, hr.	Atom-percent of excess N^{15} in atmosphere	Slightly saponified amide fraction of nitrogen			Unsaponified amine fraction (nitrogen residue after dist. of amide N in form of NH_3)		
			Total nitrogen content N_{mg} per container	Atom-percent of excess N^{15}	Labeled nitrogen as % of total nitrogen of fraction	Total nitrogen content N_{mg} per container	Atom-percent of excess N^{15}	Labeled nitrogen as % of total nitrogen of fraction
Lucerne	24	0.88	7.52	0.43	49.4	11.0	0.07	7.9
Lucerne	24	1.17	6.79	0.44	37.7	10.19	0.13	11.1
Lucerne	40	0.80	2.24	0.31	38.7	3.92	0.10	12.5
Lucerne	90	0.78	7.20	0.41	52.5	12.4	0.15	19.2
Lupine	48	0.72	6.6	0.46	65.2	24.2	0.20	27.7

Table 5

Changes in content of labeled nitrogen in separate fractions of cell sap of nodules of of legumes when N_2^{15} atmosphere is replaced by ordinary atmosphere

Plant	Conditions of experiment	Content of labeled nitrogen as % of total nitrogen of fraction		
		Total water-soluble nitrogen	Slightly saponified amide nitrogen	Amine nitrogen
Alfalfa	48 hrs. in N_2^{15} atmosphere	35.0	49.1	19.5
Alfalfa	48 hrs. in N_2^{15} atmosphere and then 24 hrs. in ordinary atmosphere	12.2	13.7	10.5
Alfalfa	48 hrs. in N_2^{15} atmosphere and then 48 hrs. in ordinary atmosphere	2.4	2.1	2.4
Clover	48 hrs. in N_2^{15} atmosphere	44.5	62.0	23.0
Clover	48 hrs. in N_2^{15} atmosphere and then 24 hrs. in ordinary atmosphere	14.6	12.4	15.6
Clover	48 hrs. in N_2^{15} atmosphere and then 48 hrs. in ordinary atmosphere	3.8	3.2	3.0

crease occurred first and foremost in the iide fraction, where the labeled nitrogen ntent decreased four to five times, while the amine fraction it was reduced by only e and one-half to two times. This is quite derstandable, for in this case the fixed dinary nitrogen first becomes part of the iide group compound, and consequently the beled nitrogen fixed earlier in this group was ore rapidly replaced by ordinary nitrogen in e ensuing atmosphere change.

A fuller idea of the intensity of the process molecular nitrogen fixation in nodules and of e speed with which the newly fixed nitrogen comes part of the nitrogenous substances of e separate organs of legumes can be gained om the experimental results with pea shown in Table 6.

When the exposure period is relatively short (24 hours), labeled nitrogen is found in its greatest quantities in the water-soluble fraction of the nodules, i. e., in their cell sap. This confirms the fact that it is precisely in this fraction of the nodules that nitrogen fixation is localized. As can be judged by the degree to which the separate nitrogenous fractions of the plants become enriched by isotope N^{15}, the fixed nitrogen passes through the roots immediately adjacent to the nodules, entering first the stems, and then the leaves of the plants.

In the first 24 hours the newly fixed nitrogen in the nodules remains largely in the form of

Table 6

Content of total and labeled nitrogen in non-albuminous and albuminous fractions of separate organs of pea

Organs of plants	Dry weight, g per container	Water-soluble non-albuminous nitrogen (asparagine and amino acids)		Albuminous nitrogen		Nitrogen of all fractions, mg N per container	Labeled nitrogen, mg N per container
		Total nitrogen mg N per container	Labeled nitrogen as % of total	Total nitrogen, mg N per container	Labeled nitrogen as % of total		
24 hr. exposure. Atom-percent of N^{15} in excess of atmosphere: 1.15							
Nodules	5.5	13.5	53.0	34.4	10.3	47.9	10.7
Roots[a]	8.0	10.5	22.3	24.2	2.4	34.7	2.6
Roots[b]	50.0	31.2	10.3	67.4	0.0	98.6	3.2
Stems	68.0	75.3	19.3	128.7	0.4	204.0	15.0
Leaves	46.0	80.1	6.3	214.4	0.4	294.5	6.4
Total	177.5					679.7	37.9
72 hr. exposure. Atom-percent of N^{15} in excess of atmosphere: 1.03							
Nodules	5.3	13.4	41.7	37.3	25.3	47.7	14.35
Roots	7.9	10.7	33.0	24.5	6.0	36.2	5.01
Roots	42.0	30.9	23.0	68.1	4.9	99.0	10.64
Stems	67.8	79.9	33.0	126.5	16.5	206.4	47.17
Leaves	46.3	80.3	21.9	215.2	12.9	292.5	45.20
Total	169.3					681.8	122.37

[a] Roots and their parts immediately adjacent to nodules.

[b] Roots further away fron nodules.

non-albuminous compounds (amides and amino acids). But after 72 hours the fixed labeled nitrogen was found in the albumins, the largest quantity being in the stems and a lesser amount in the roots and leaves. In all, with a total plant mass of some 180 g, 122 mg of nitrogen fixation in 24 hours being about 40 mg. Roughly the same results were obtained with alfalfa, lupine and clover.

Since it is in the nodule tissue of the higher plant that the fixation of atmospheric nitrogen takes place, any change in its intensity is conditioned first and foremost by the state of the higher plant. Clearly, the nodule tissue's activity as a nitrogen-fixing system depends upon some substances produced in the other organs of the higher plant flowing into the tissue. When environmental conditions are unfavorable for the plants' growth or when they get old, less of these substances are produced in them and the catalytic activity of the nodule tissue declines.

This conclusion also emerges from experiments in studying the light effect upon symbiotic nitrogen fixation in lupine, the results of which are given in Table 7.

These experiments were carried out at the same time in a greenhouse. To shade the plants a black cotton fabric was hung on the glass chambers in which they were housed. In normal light there was intensive nitrogen fixation; but it fell sharply and virtually ceased altogether when the plants were left without light, both during the experiment and in the 48 hours immediately preceding the experiment.

From the results of these experiments it follows that light is essential for the formation in the plants of the substances which are absolutely indispensable if nitrogen fixation in the nodule tissue is to be possible. The nature of these substances is not known, but it may not only be a question of carbohydrates. Towards the end of the experiment there still remained a very considerable quantity of carbohydrates (mono- and disaccharides) in all parts of the plants, even in the worst treatment, with 96 hours of darkness (48 hours

Table 7

Influence of light on atmospheric nitrogen fixation in lupine nodules exposed for 48 hours in atmosphere enriched with N_2^{15}

Nitrogen groups isolated from lupin nodules	Normal lighting		Darkness throughout experimental period		Darkness of 48 hrs. before experiment and throughout experimental period	
	Atom-percent of N^{15}	Labeled nitrogen as % of total	Atom-per-cent of excess N^{15}	Labeled nitrogen as % of total	Atom-per-cent of surplus N^{15}	Labeled nitrogen as % of total
Amide nitrogen of nodule cell sap	0.46	65.2	0.20	27.7	0.03	4.1
Amide nitrogen of nodule cell sap	0.20	27.7	0.08	11.1	0.02	2.8
Bacterial nitrogen	0.14	19.4	0.02	2.8	0.01	1.4

	Normal lighting	Darkness throughout experimental period	Darkness of 48 hrs. before experiment and throughout experimental period
Total nitrogen fixed in whole plant during experiment, mg N per container	58.8	7.7	0.95
Total content of mono- and disaccharides in all organs of lupine, g per container	7.11	5.90	3.61

ring the experiment and 48 before it). There-
re, in this case they cannot have limited fix-
ion. Hence, it was some other substance,
nthetized in the plant in light ones, that pro-
ced nitrogen fixation. A continuous flow
to the nodule of this substance, which for con-
nience we shall call factor A, is an indispens-
le condition for the process of molecular ni-
ogen fixation occurring in its tissue.

Nitrogen fixation can occur in nodules iso-
ted from plants for a very limited period of
ne and only so long as these substances (fac-
r A), which have earlier entered the nodule
om the leaves of the higher plant, are not
ed up. This is confirmed by subsequent
ta in Table 8.

In nodules freshly separated from plants,
trogen fixation — as could be judged from
eir N^{15} isotope content — decreased sharply,
d in nodules separated from plants 24 hours
fore the experiment began the labeled nitro-
n content was so low that it little exceeded
e experimental error in isotope analysis.
e complete absence of labeled nitrogen in
nodules freshly separated from the plant, but ground, shows that molecular nitrogen fixation in nodule tissue is associated with the latter having a definite structure. When this structure is destroyed nitrogen fixation cannot occur.

The intensity of nitrogen fixation in isolated nodules is not apparently limited by lack of carbohydrates. The research carried out showed that in these experiments the total content of mono- and disaccharides in nodules immediately separated from plants constituted 2.67% of the dry weight of the nodules. After a 24 hour exposure of nodules in a labeled nitrogen atmosphere or in the normal atmosphere of a moist chamber the content of soluble carbohydrates in the nodules diminished for understandable reasons, and its average for a number of experiments comprised about 1.7% of the dry nodule weight. Indeed, this is a very considerable amount. Therefore, there cannot be any question of any lack of carbohydrates for normal fixation of nitrogen in a nodule. There is no doubt that some other substances apart from carbohydrates enter the nodule from the plants' leaves: the presence of these is indis-

Table 8

Content of labeled nitrogen in amide fraction separated from cell sap of alfalfa nodules isolated or not isolated from plant

Condition of experiment	Atom-percent of excess N^{15} in amide group		Labeled nitrogen as % of total amide nitrogen	
	Experiments			
	I	II	I	II
Nodules separated from plants were immediately placed in atmosphere enriched with N^{15} for 24 hrs.	0.24	0.19	21.0	18.3
Nodules were placed in chamber containing N_2^{15} 24 hrs. after separation from plants	0.08	0.00	7.0	0.0
Nodules separated from plants were immediately ground and placed in chamber containing N_2^{15} for 24 hrs	0.00	0.00	0.0	0.0
Nodules on plants in natural condition	0.64	0.44	56.5	40.0

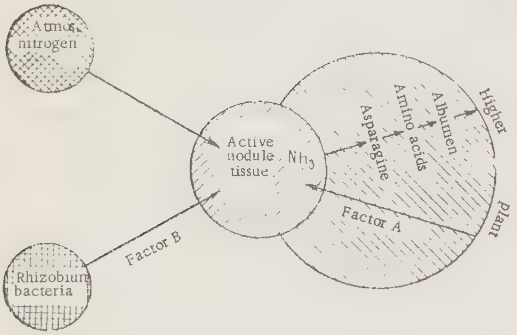

Fig. 1. - General plan of process of atmospheric nitrogen fixation in nodules of legumes.

pensable for molecular nitrogen fixation in the nodule tissue.

The results of research into the fixation of molecular nitrogen in the nodules of leguminous plants can be expressed in the form of a plan, as follows (see Fig. 1).

Rhizobium bacteria, penetrating the legume roots, secrete a substance (factor B) which induces the formation of nodule tissue, on the surface of which atmospheric nitrogen fixation takes place. But this process can only occur in the event of the nodule tissue receiving supplies of a certain specific substance (factor A) which is synthesised in light in the legume leaves. The first product of fixation is ammonia, which is quickly transformed into the amide group of asparagine. The latter, being the transportable form of ammonia in the plant, is used in the synthesis of amino acids, which help to build the albumin both of the higher plant and of the bacteria which cohabit with it.

Conclusions

1. During the experiments a study was ma of the intensity of the incorporation of N^{15} in different nitrogen fractions isolated from sep- arate organs of alfalfa, red clover, pea and l pine, these plants having been exposed in an atmosphere enriched with N_2^{15} between 12 and 90 hours. During the investigation an isolation method of Rhizobium bacteria from nodules was evolved, which also made it possible to study the rate of N^{15} incorporation in bacte ial cells at the same time.

2. With a relatively short exposure (12-24 hours) of legumes in an atmosphere of N_2^{15}, fixed labeled nitrogen is found in very high co centrations only in the cell sap of nodule tiss and in considerably lesser concentrations in t cell sap of roots, stems and leaves. In nodul bacteria (Rhizobium), with between 12 and 24 hours of plant exposure in an atmosphere of N_2^{15}, there is a complete absence of labeled nitrogen, or it is present in insignificant con centrations which do not exceed the experimental error. Thus, atmospheric nitrogen fixation does not occur in nodule bacteria but in the nodule tissue of the higher plant. The role of the bacteria (Rhizobium) is apparentl that of inducing the formation of this specific nodule tissue.

3. If the period of exposure in an atmosph of N_2^{15} is longer, labeled nitrogen is also fou

bacteria, but in this case too enrichment of
e bacterial nitrogen is considerably lower
n the corresponding amounts for the nitro-
n of nodule cell sap and for nitrogenous frac-
ns of the higher plant's other organs.

4. With the plants in darkness the intensity
N_2^{15} fixation in the nodules of legumes sharp-
decreases, and with longer periods of ex-
sure in darkness (72-90 hours) it ceases
mpletely, despite the fact that considerable
antities of soluble carbohydrates may in this
se be present in the plants.

5. In nodules separated from plants, nitro-
n fixation occurs considerably less intensive-
and only in the first few hours after separa-
n of nodule and plant. Labeled nitrogen does
t in practice become part of nodules which
ve been separated from plants 24 hours be-
re having been placed in an N_2^{15} atmosphere,
of nodules which have been ground. Thus,
nospheric nitrogen fixation is associated
th a definite structure of the nodule tissue,
d for it to occur there must be a flow of some
ecific substances from the above-ground or-
ns of the higher plant. For the synthesis of
ese substances light is essential.

6. Of all the nitrogenous compounds contained
nodule cell sap it is always in asparagine that
e maximum enrichment with isotope N^{15} is to
found, regardless of the period of the plants'
posure in an N_2^{15} atmosphere. In asperagine-
e glutaminic, and other amino acids they con-
n considerably smaller quantities of labeled
rogen. In asparagine, labeled nitrogen is
ntained largely in its amide group. Since
e latter can be regarded as transformed
nmonia, then it follows that ammonia is one
the primary products, if not the first prod-
t, of the biological fixation of atmospheric
rogen in the nodules of leguminous plants.

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GENESIS OF EXCHANGEABLE ALUMINUM IN SOILS

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On the basis of much experimental data, both from the literature and our own, we have reached the conclusion that the acidity of the mineral part of the podzolic soil and red earths is fundamentally conditioned by the fact that they contain aluminium ions in an adsorbed state. This conclusion proceeds from:

1) the equivalence between titratible acid and aluminium content in KCl — extracts from natural podzolic soils and red earths; 2) the higher energy of adsorption by soils of aluminium ions as compared with the hydrogen ions; 3) the curves of potentiometric titration of salt and water soil suspensions and aluminium salts with solutions of bases; 4) establishment of the conditions governing the existence of different forms of aluminium in solution and solid phase; 5) study of the hydrolysis of aluminium salts and of the establishment of a mathematical relation between concentrations of hydrogen and aluminium ions in aluminium salts; 6) the use of methods enabling relatively precise determination of hydrogen and aluminium ions when both are present together in a solution; 7) establishment of the effect of alkalization of NaF solution interacting with acidic podzolic soils and red earths; 8) change in the adsorption equilibrium of the KCl — suspension of red earth with its dilution towards increased adsorption of aluminium ions, and also on the basis of much other data.

We determined the exchangeable acidity of soils after exchangeable cations had been artificially removed from them by means of 0.05 N HCl treatment or electrodialysis. It turned out that the content of aluminium ions in a KCl — extraction from such soils was several times greater than that of hydrogen ions.

As is known, in electrodialysis exchangeable cations in soil are replaced by hydrogen ions, the source of which is water. In the electrodialysis process there is no formation in the water soil suspension of a large concentration of acid which could transfer the aluminium ions into a solution that would then become adsorbed. It would seem that after electrodialysis we should obtain soil saturated with hydrogen ions.

In order to explain the appearance of aluminium ions in the solution when electrodialize soil interacts with a KCl solution it was necessary either to adopt the hypothesis of the "exchangeable hydrogen ion" or assume that there are processes in electrodialized soil which result in aluminium ions entering into an exchang able state. On the basis of all our experimental data and in accordance with Marshall's idea (20) we made the assumption that the replacement of exchangeable cations by hydrogen ions must be accompanied by a reaction between th colloidal particles containing hydrogen ions in an adsorbed state and the basic aluminium forn present in the solid phase. This reaction lead to the aluminium ions entering into the soil adsorptive complex (6).

We have therefore explained the appearanc of aluminium ions in the solution when artificia ly non-saturated soils with KCl solution interact as a direct exchange of potassium cations for exchangeable aluminium ions. The overwhelming majority of papers appearing in the press after the publication of our monograph (6) confirmed and developed its arguments. For example, experiments conducted jointly in 1950-1951 with Kislitsina (7-9) showed that if soil samples were first treated with HCl sol tion and then with KCl solution, then again wit HCl and again with KCl and so on, then in the equilibriated KCl solution, regardless of how the soil samples are treated with hydrochloric acid, both hydrogen and aluminium ions are always present. If, after rinsing the soil sam ples in hydrochloric acid (and rinsing its exce they are not treated with KCl solution immediately, but only after several days, then the content of aluminium ions in the equilibriated solution increases and the quantity of hydroge ions diminishes.

In other words, the correlation of the hydr

In other words, the correlation of the hydro- n and aluminium ions displaced by the KCl solu- on depends upon the time that has passed be- een the treatment of the soil with acid and its eatment with KCl solution. The longer this me is, the fuller the reaction of the replace- ent of adsorbed hydrogen ions by aluminium ns and, hence, the higher the content of alu- inium ions in the KCl filtrate and the lower at of hydrogen ions.

U. H. Slabaugh (23) gives data for potentio- etric titration and heats of neutralization of entonite deprived of exchangeable cations by eans of electrodialysis or passing the bento- te suspension through H-resin. From these ta the author drew the conclusion that there e two types of hydrogen ions in H-bentonite. ydrogen ions of the first type are fully dissoci- ed, for their neutralization releases only as uch heat as would be released in the neutraliza- on of an equivalent quantity of any strong acid Cl, H_2SO_4, and others). Hydrogen ions of e second type are less dissociated, for their utralization releases less heat. In potenio- etric titration of bentonite with an alkali lution, hydrogen ions of the first type titrate lower pH — values compared to the second pe. In the bentonite sample obtained by ectrodialysis the quantity of hydrogen ions the first type is less, and that of the second pe is correspondingly more than in the sample the same bentonite obtained by passing its spension through resin. With the condition- g of the bentonite obtained by the methods ferred to over a period of 60 days the quantity hydrogen ions of the first type diminished, d the quantity of those of the second type in- eased.

On the basis of Chernov's and Kislitsina's ork (8), and the data given below, it is clear at hydrogen ions of what Slabaugh called the cond type are in reality exchangeable alumin- m ions.

In Coleman's paper (14), and two of his papers th Harward (15, 17), data are given for heats neutralization and potentiometric titration of -resins, Al-resins and bentonites, the ex- angeable cations having been removed from em at various rates (great and small). The pid removal of exchangeable cations from the ntonites was carried out either by passing eir suspensions through H-resin, or by eatment with a 1.0 N HCl solution. Slow re- oval was carried out by electrodialysis, or means of treatment with a 0.05-0.10 N HCl lution. Both in the forms of their potentio- etric titration curves and in their heats of utralization clays treated with 1.0 N HCl solu- on or passed through H-resin are largely turated with hydrogen ions; and the same ays treated with 0.05 N HCl solution or electro- alized are largely saturated with aluminium ns.

In the potentiometric titration with NaOH solution of clays which simultaneously contain both hydrogen and aluminium ions in an exchangeable state, first the hydrogen ions titrate (are replaced by sodium cations) at lower pH-values, then the aluminium ions titrate at higher pH-values.

P. F. Low (18) used an original method of obtaining bentonite saturated either with hydrogen ions only or with aluminium ions only, or with both at the same time, their ratio in the latter case being different Experiments in potentiometric titration with NaOH solution of the bentonite samples obtained showed that, firstly, with lower pH-values, the hydrogen ions are replaced by sodium cations, and then, the replacement of aluminium ions takes place, with higher pH-values.

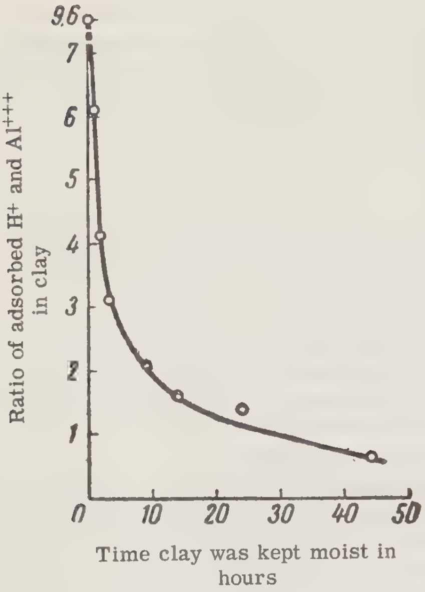
McAufliffe and Coleman (19) prepared resin and bontonites saturated either with hydrogen or aluminium ions, and studied them as catalytic agents in the hydrolysis of acetic-ethyl either and the inversion of cane sugar. The experiments showed that when saturated with hydrogen ions bentonites and resins are many times more active catalytic agents than they are when saturated with aluminium ions.

Thus, literature and experimental data confirm our previous conclusion that clay saturated with hydrogen ions is in an unstable state. A spontaneous reaction occurs in clay of this kind, as a result of which the clay becomes saturated with aluminium ions, i. e., it attains a state of greater stability.

All the works referred to were qualitative in character. So in order to obtain a more vigorous confirmation of the spontaneous reaction of the replacement of hydrogen by aluminium ions we made a quantitative study of the kinetics of this reaction in Askangel clay (10).

The method of work was as follows: A series of clay samples were treated several times with 1.0 N HCl solution. Then, the excess HCl having been removed, they were treated with 1.0 N KCl solution. The removal of HCl from the clay samples and their treatment with KCl solution was done as quickly as possible by using a centrifuge.

One clay sample was treated with KCl solution immediately after removal of excess HCl. The others were similarly treated after conditioning in a moist state for definite intervals of time. Figure 1 shows the data obtained from the clay samples conditioned in water at a temperature of 50°C. In the KCl filtrate obtained for clay which had not been conditioned, of the total hydrogen and aluminium ions, 90.6% were found to be hydrogen and 9.4% aluminium; and the H^+/Al^{+++} ion ratio = 9.6. In the filtrates of clays which had not been conditioned the



Change in $\frac{H^+}{A^{+++}}$ depending on time.

aluminium ion content rose as the time interval increased, and the hydrogen ion content fell. For example, when the clay was conditioned for a period of 44 hours the hydrogen ion concentration in the filtrate was lower than the aluminium ion concentration and hence the H/Al ion ratio became less than one, i. e., there were more aluminium ions in an adsorbed state in this clay sample than there were hydrogen ions.

The curve for H^+/Al^{+++} quantities found in the KCl filtrates for the times during which the H-clay was conditioned represents a hyperbolic type. From the form of the curve it can be seen that the rate of change in the H^+/Al^{+++} quantity is at first very sharp, and that it then decreases gradually, more and more slowly, but continuously. We set up experiments to study the influence of the temperature in which the H-clay was conditioned on the rate of spontaneous reaction of the replacement of the hydrogen ions by aluminium ions. These experiments showed that higher temperatures increased the reaction rate very sharply. This proved that when clay interacts with KCl solution there is an exchange between potassium cations and the hydrogen and aluminium ions present in the clay in an exchangeable state. It is quite clear that had the cations of the solution exchanged only with hydrogen ions, and had the appearance of the aluminium been the result of a second chemical reaction between the acid formed and the clay, then regardless of the period for which the clay had been conditioned we should have found identical quantities of hydrogen ions and correspondingly equal quantities of aluminium ions in all the KCl filtrates. Actually, however, the titratible acid of the KCl-extract from the freshly prepared clay sample is conditioned almost wholly by hydrogen ions; and that from the sample which had been in solution for 44 hours is conditioned by aluminium ions to a greater degree than by hydrogen ions. Simila experiments were carried out with red earths the Chinese scientists Lin Yung-shao and Yui Tian-shen (4), of the Soil Science Institute of the Chinese Peoples' Republic, Academy of Sciences. They reached the following conclusions:

1) The replacement reaction of hydrogen ions by aluminium ions takes place very quickly; 2) the replacement reaction rate is influenced by the nature of the adsorption complex; 3) soil saturated with hydrogen ions is unstabl and in natural conditions hydrogen ions which have entered into the exchangeable state are replaced by aluminium ions.

The paper by Bolt and Warkentin (13) gives curves for the potentiometric titration of bentonite, the exchangeable cations of which had been removed by electrodialysis (first method) or by passing it through H-resin (sec method).

Bentonite prepared by the second method was titrated with alkali either immediately after it had been prepared or after it had been conditioned for two hours, two days, 10 days and 91 days after its preparation. The titration curve of the electrodialized bentonite lies in the range of pH-values in which exchangeab aluminium ions precipitate in the form of hydrate. The titration curve for freshly prepar bentonite obtained by the second method, however, is similar to the titration curve for 0.01 N HCl solution and lies, accordingly, at low pH-values.

As the conditioning period of the bentonite increased the titration curve gradually moved towards higher pH-values, and in the case of the sample kept for 91 days it almost coincide with the titration curve of the electrodialized bentonite. The change of the titration curve o H-bentonite as its conditioning period increas is easily explained as being a result of the reaction of the aluminium ions replacing the hydrogen ions in it. The concurrence of the titr tion curves of electrodialized bentonite and H-bentonite kept for 91 days indicates that the composition of their exchangeable cations is identical, i. e, that in both samples of bentoni exchangeable aluminium ions predominate ove exchangeable hydrogen ions.

We studied the spontaneous reaction of the replacement of hydrogen ions by aluminium i by conditioning the clay for a short period of time (12). A study of this reaction over a lon period seemed of great interest. Such experiments have in fact been carried out by us (11, with the same montmorillonite type of clay skangel).

In the initial clay sample the content of exngeable magnesium was 5% and of exchangee calcium 47.5% of the total capacity. As in experiments described previously, a series clay samples were saturated with hydrogen s. After conditioning the clay in a moist te at a temperature of 50°C for three, twelve l thirteen days and for four months in KClracts, the content of hydrogen and alumin ions was determined. The experiments owed that the exchangeable acidity, i.e., the al of hydrogen and aluminium ions in the KCl rate diminished as the conditioning period the clay increased from three to thirteen s. The data obtained, and Marshall's and inbill's indication (20) that after electrodialy- the attapulgite changes its reaction from d to neutral and that magnesium from the tice passes into an exchangeable form, ened the assumption that in the montmorillon- clay which we were studying exchangeable lrogen ions can also be replaced not only by minium ions, but by other cations too. erefore in the KCl-extract from the clay mple which had been conditioned for four nths the total Mg and Ca cations, as well as and Al^{+++} ions, was determined by titration h trilon B. The total exchangeable acidity and changeable Mg and Ca for this period turned to be close to the exchangeable acidity of clay when conditioned for a short period ree days). Then the experiments of condining the clay for different periods were peated. After each conditioning period in a l-extract the pH-values, the content of hygen and aluminium ions, and the total of and Ca cations were determined from the y. The data of these experiments are given Table 1.

From these data we see that as the period of nditioning of the clay samples in a moist state reases there is a gradual transition of alunium, magnesium and calcium ions from a n-exchangeable into an exchangeable state. e total exchangeable H^{+}, Al^{+++}, Mg^{+++} and $^{++}$ in the clay in all three conditioning periods mains to all intents and purposes a constant ntity. Thus, the quantity of hydrogen ions ssing from an exchangeable into a non-exngeable state is equivalent to the total ntity of Al, Mg and Ca ions passing from a n-exchangeable to an exchangeable state.

The reaction of the replacement of exchangee hydrogen ions by the cations referred to ds, as was to be expected, to a gradual inease of the soil suspensions pH-values.

D. L. Askinazi, N. P. Karpinskiy and N. P. mezov published an article (3) disputing rtain of our theses (6). The article contains experimental material at all and perpetrates a number of major errors.

Making use of one new work (by M. E. Harward and N. T. Coleman [17]), these authors have expounded its argument incorrectly. Furthermore they maintained that "a direct method of proving the role of aluminium in creating the exchangeable acidity of soils has not been found. The only argument therefore continues to be indirect proof, which is always furnished by less trustworthy and more questionable evidence." This idea is erroneous. In actual fact the majority of physical quantities are not usually measured directly, but by means of calculations from mathematical relationships established between different phenomena, that is to say indirectly.

"We have to resort to such methods (calculations)," writes the well-known physicist K. P. Yakovlev, "because direct measurements of different physical quantities in the great majority of cases could give insufficiently accurate and reliable results or would be very complicated, and sometimes quite impossible" (12).

All the modern methods used in soil science (spectrographic, spectrophotometric, colorimetric, potentiometric, radioactive and others) are not direct, but indirect. Despite this on one doubts their reliability. Hence the reliability, or probability, of experimental data is determined not by how such data are obtained (directly or indirectly) but by other considerations. To confirm their idea that indirect proof is furnished by less trustworthy data D. L. Askinazi, Karpinskiy and Remezov write as follows: "From this point of view the results of Harward's and Coleman's work (17) merits attention: they assess the composition of ions introduced into acidified clays by determining heats of neutralization and not by the usual analysis of the composition of salt extracts from these clays which have an acid reaction. Harward and Coleman have shown that in soil acidification by means of consistent and lengthy treatment with 0.05-0.1 N HCl (the usually accepted method) aluminium ions, not hydrogen ions, do in fact pass into the adsorptive complex; on the other hand when weaker acidifiers are used — the authors pass suspensions of their clay fractions through a column of artificial H-cations (H-amberlite and other resins) — it is on the contrary not aluminium ions, but hydrogen ions which pass into the adsorption complex of these clays."

Hence, Askinazi and his fellow authors regard the strength of the acid used in the treatment of the clay as the basic reason for the clay's saturation with H or Al ions, in as much as when the clay was treated with 0.05 N or 0.1 N HCl it was found to be saturated with Al ions, whereas when treated with weak acidifiers it was saturated with hydrogen ions.

Table 1

Change of content of H, Al and Mg exchangeable ions depending upon time of conditioning clay (50°)

Time of conditioning clay	pH of KCl filtrate	Titratible acid meq, $\frac{}{100\ g}$	Aver.	$\frac{\text{meq Al}}{100\ g}$ clay	Aver.	meq $\frac{\text{Mg+ Ca}}{100\ g^a}$	Aver.	Total titratible acid of Mg and Ca $\frac{\text{meq}}{100\ g}$
3 days	2.74 2.75 2.74 2.77	81.4 83.2 83.2 81.7	82.4	35.4 34.5 37.0 36.6	36.4	4.0 4.0 4.0 4.0	4.0	86.4
12 days	2.94 2.90 2.90 2.90	71.3 72.0 74.7 74.7	72.9	50.9 51.8 51.7 53.4	51.9	8.3 8.8 8.8 8.8	8.7	81.7
30 days	3.20 3.20 3.45 3.50	70.6 72.0 69.2 72.0	71.0	57.3 57.3 60.0 63.8	59.7	14.3 14.3 14.3 15.1	14.5	85.5
4 months	3.85 3.86 3.78 3.79	74.0 72.0 72.0 72.0	72.5	53.4 55.9 56.1 55.2	55.2	14.5 14.7 13.6 14.0	14.2	86.7

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[a] Mg ions considerably predominate over Ca ions.

In fact, however, Harward and Coleman obtained clay saturated with hydrogen ions by treating it with 1.0 N HCl solution, and not only when treating it with weak acidifiers. It follows that the strength of the acidifier applied in the treatment of the clay is of no significance for its saturation with H or Al ions.

Howard's and Coleman's basic conclusion is that clay saturation (by H or Al ions) depends upon the speed with which exchangeable cations are removed from it. When the removal of exchangeable cations from clay (by treatment with 0.05-0.1 N HCl or by means of electrodialysis) is slow it is saturated with aluminium ions; when the removal of exchangeable cations (by treatment with 1.0 N HCl solution or by passage through H-resin) is fast it is saturated with hydrogen ions.

Di Gleria (16) considers the appearance of aluminium in a salt solution to be a result of a second chemical reaction between the acid formed in the exchange reaction and the solid phase of the soil.

Aleshin takes up a special position on the problem of soil acidity. He does not believe that neither hydrogen ions nor aluminium ion can be in an exchangeable state (1, 2). Aleshin's ideas contradict not only the classical experimental data furnished in recent years b Gedroyts and other authors, but also his own data.

In actual fact, according to Aleshin, and in conformity with many researchers' experiments, the titratible acid of a KCl extract from electrodialized clay is conditioned by aluminium ions. The passing of aluminium ions into KCl solution is only possible from a exchangeable state as a result of their being displaced by potassium cations. Aleshin, h ever, explains the passing of aluminium ions into KCl solution not as an exchange reaction but as decomposition of the clay in its process of interaction with the potassium chloride sol tion. It is well known that under certain circumstances (at high temperatures) clay mine als can break down into their component part i. e., into Al_2O_3 and SiO_2, but it is very difficult to imagine that their decomposition coul be attended by the formation of trivalent alum ium in the absence of exchangeable hydrogen

On the basis of the experimental data we have tained, it can be considered proved that when changeable cations in clays and soils are pidly replaced by hydrogen ions the latter come exchangeable, capable of being replaced cations of neutral salts. However, hydrogen ns in H-clays are fairly mobile and react with definite rate with the basic forms of aluminium. a result of this spontaneous reaction the ex- angeable hydrogen ions form water molecules d pass from an exchangeable into a non-ex- angeable state; the basic non-exchangeable rms of aluminium, however, losing hydroxyl ns on atoms of oxygen, change into aluminium tions and enter into an exchangeable state, cupying the adsorbed places earlier occupied hydrogen ions.

In other words, as a result of the spontaneous action referred to, hydrogen ions in an ex- angeable state are replaced by aluminium ions.

It is known from literature data (5) that agnesium is part of the crystal lattice of ontmorillonite. Our experiments have shown at in H-clay exchangeable hydrogen ions are placed not only by aluminium ions but also magnesium ions, the source of which are changeable forms of magnesium of the cry- al lattice. Therefore the replacement of hy- ogen ions by aluminium ions also probably kes place at the expense of aluminium form- g part of the crystal lattice of montmorillonite.

In the light of these ideas the experiments the kinetics of removing exchangeable cations electrodialysis conducted by Mattson (21, 22) d other researchers become comprehensible. ese experiments showed that under electrodi- ysis the rate of removal of Ca, K and Na ex- angeable cations gradually diminishes, and at of Mg, Al and Fe cations increases. In ectrodialysis cations in an exchangeable ate are removed first and hydrogen ions ter into an exchangeable state in their place. ter this, as a result of spontaneous reaction, uminium and magnesium cations pass from a n-exchangeable to an exchangeable state and erefore become capable of electrodialysis. also becomes clear from the ideas ex- nded previously why it is that in the course very lengthy electrodialysis clays of the ontmorillonite type can partially or even olly lose exchangeable capacity.

Conclusions

1. When exchangeable cations are rapidly moved from montmorillonite type of clays treatment with 1.0 N HCl solution or by ssing their suspensions through H-resin the lloidal clay particles become saturated with changeable hydrogen ions.

2. Hydrogen ions in an H-clay are fairly mobile and for this reason enter into a chemical reaction with the non-exchangeable basic forms of aluminium and magnesium forming part of the structure of the crystal lattice of montmorillonite.

3. As a result of the spontaneous reaction referred to the hydrogen ions pass from an exchangeable into a nonexchangeable state, whereas aluminium and magnesium ions pass from a non-exchangeable into an exchangeable state.

4. Exchangeable hydrogen ions are replaced equivalently by aluminium and magnesium exchangeable ions.

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IFLUENCE OF ROCKS UPON SOIL FORMATION PROCESSES

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The great influence of soil-forming parent
terial upon the processes of soil formation
s been known since the days of V. V. Doku-
ayev. However, now that a great quantity of
tual material has accumulated, it is in our
nion urgently necessary to return to this
stion and analyze the available written data
m the zonal point of view. This will un-
ubtedly resolve a number of genetic problems
l help to identify more precisely certain links
the chain of soil classification and soil-form-
parent material.

Particular attention, we believe, should be
d to sedimentary rocks, the basic mass of
y minerals formed as a result of weathering
l soil formation processes in by-gone epochs.
ey have naturally undergone complex trans-
mations in the process of diagenesis; never-
less in a number of cases they have pre-
rved features left over from the distant past.
have in mind certain types of clays, chlorite
l sericite slates possessing high potential
dity and containing a very small quantity of
aline-earth cations.

Unfortunately soil scientists have hitherto
y studied the specific features of soil forma-
n processes on parent material containing a
h quantity of both silicic and carbonate cal-
m and magnesium. But no light has been
d on the influence of parent material low
content of alkaline-earths, or even possessing
ential acidity, upon soil formation processes,
hough in a number of cases the acid reaction
C horizons has been fixed (brown forest
ls, soils on red-colored weathering crusts
he sub-tropics and tropics). Quite obviously
presence of considerable potential acidity
he parent material sharply changes the course
l direction of the elementary soil processes
and in different ways according to different
climatic zones.

We shall illustrate the foregoing with factual
terial characterizing the soils formed on
entially acid parent material in different soil
es.

Podzolic Soils. We have observed a group of podzolic soils, formed on parent material containing a great quantity of mobile exchangeable aluminium and possessing acid reaction, in the southern part of the Central Urals.

This material consisted of thin slightly-weathered eluvium of clay, sericite and chlorite slates. A small piece of nonweathered (stable) slate, when pulverized in an agate mortar, showed an acidic reaction. The pH-value of a salt suspension from the pulverized piece of material was 4.5-5.0. Determining the exchangeable acidity in the pulverized sample by A. V. Sokolov's method, we found it contained a considerable quantity of mobile aluminium (6-15 meq per 100 g of powder).

From the first phases of their development, soils formed on such parent material possess a considerable amount of acidity and non-saturation with bases, without the slightest signs of podzolization. With further development of the profile a podzolic horizon makes its appearance. We have observed such soils under the mossy-grassed surface encountered in fir forest, with an admixture of birch and a young growth of basswood, dog rose and mountain ash.

Here is a morphological description of the profile of the soils characterized:

Profile 185. On road from Vitimo — Utkinsk to Ashka mine. Middle third of slope gradient 5-6°. Fir and birch forest with mossy-grass ground cover.

A_0 0-3 cm. Slightly decomposed litter and shallow sod.

A_1A_2 3-22 cm. Brownish-grey; nutty to blocky structure. Sprinkling of silica material clearly noticeable. Transition to lower-lying horizon gradual.

A_2B 22-35 cm. Greyish-brown, nutty to blocky structure. Sprinkling of silica material clearly noticeable. Transition to horizon B gradual.

B 35-55 cm. Reddish-brown, with sparse sprinkling of silica material in form of deposits in cracks. Compact. Nutty to blocky structure. Clay. Rubble of parent material encountered.

CD 50 cm. Slate marl with small quantity of fine earth.

As we see from the description, the soil has in fact a fairly well-marked profile differentiation into genetic horizons, although the transitions from one horizon to the next are still gradual — a feature characteristic enough of soils which have developed on eluvium and eluvio-deluvium of slates. Furthermore, in field operations in the areas described it was found that soils developed on eluvio-deluvium of slates, despite the low pH-values of soils and parent material, were less podzolized than those which had developed in analagous conditions upon eluvio-deluvium of other compact parent materials, including carbonate.

Let us turn to the analytical indices for the soils concerned. Table 1 gives soils that have formed on different parent materials, but whose development has taken place in exactly the same soil formation circumstances.

As the values show, soils developed on eluvio-deluvium of slates have a very wide degree of base unsaturation throughout the profile; the highest quantity having quite often been observed in horizon C. Thus the soils' base unsaturation and non-acquired acidic reaction during formation are features inherited from the parent material.

Comparing soils formed on slates with those formed on limestone eluvium and on a relatively wide thickness of deluvial clay loam we see that the sod process differs. Soils developed on deluvial clay loams and eluvium of carbonate parent material show a clear biological accumulation of ash elements in the humus horizons. As a result of this the horizons have a relatively wide degree of base saturation and a less acidic reaction compared to the lower-lying horizons.

But in soils formed upon eluvio-deluvium of slates the sod process e[illegible] does not appear at all, or manifests itself [illegible] feebly. Although the litter (A_0) of [illegible]ow a clearly defined accumulation of bases, there is no noticeable accumulation of them in the humus horizon when they decompose and the solutions penetrate the mineral stratum. The upper horizon of these soils remains strongly acidic and strongly unsaturated. Thus the mineral mass of the soils shows a high buffer capacity as regards alkalis, owing to which these soils are able to retain their acidic reaction and wide base unsaturation for a long time. Moreover, the biological accumulation of bases (particularly calcium) is limited by their extremely low content in the over-all composition of the parent material (total content of CaO in slate is 0.47%). The low base content is one of the main reasons why only small quantities of humus are present in the surface soil horizon The humus content of soils formed on eluvium of acid slates seldom exceeds 2%-3%, wherea on other soil-forming parent material soddy-podzolic soils with a high humus content (5%-7%) are formed.

The soils show a characteristic distributio of the clay fraction in the profile as well as it adsorption capacity.

It is in the surface horizons that the greate quantity of the clay fraction is found, a fact which at first sight is contrary to the essentia nature of podzol-formation. However, this sort of phenomenon occurs fairly frequently i podzolic soils developed on rubble eluvium of the basic parent material. It is associated with the fact that in these cases the podzolic process builds upon the preceeding soil forma tion phase, characteristic of which is an accumulation of the clay fraction in the surface stratum ("primitively accumulative soils," to use Ye. N. Ivanova's definition). For this reas the surface horizons of even strongly-podzoli soils formed on eluvium of compact parent m terials do not always reveal a clearly defined clay impoverishment.

It is interesting to note the absence, in the soils described, of a direct correlation betwe the quantity of the clay fraction and the magnitude of the adsorption capacity. Having assumed conditionally that it is only the clay fra tion that possesses an adsorptive capacity we calculated the adsorption capacity of 100 g of clay in various genetic soil horizons. It turn out that the clay fraction of C horizon and thr times the adsorption capacity of A_1 horizon, which one might have expected the highest exchangeable capacity as a result of the presen organic colloids. There may be two reasons this. Either the composition of clay mineral changed considerably in the soil formation pr ess; or the methods of soil dispersion applie the particle-size analysis by Kachinskiy's me do not completely disperse the microaggregat particularly in the horizons not affected by p zol-formation, as a result of which full extra tion of the clay fraction is not obtained. It is possible that both these factors played their p to some extent, but in view of the fact that a similar picture is observed in the steppe type soil formation (which we shall refer to below we are inclined to think that the basic reason must be incomplete soil dispersion in particl size analysis. It is most probable that colloi fractions of clay minerals subjected over a p iod of several geological epochs to complex p esses of diagenesis and metamorphism, requ

Table 1

Physicochemical characteristics of podzolic soil groups developed on eluvio-deluvium of slates, deluvial clay loams and marls in central Urals

Profile No.	Name of soil	Depth, cm	% humus (Tyurin's method)	Adsorbed cations (Gedroyt's method)				pH of salt suspension	Degree of base unsaturation	Content of particles <0.001 mm in diameter	Adsorp. capacity of clay fraction, meq/100g	Total content			
				Ca	Mg	H	Total					SiO_2	Fe_2O_3	CaO	MgO
185	Medium podzolic on slate eluvio-deluvium	0—3	41.7	—	—	—	—	—	—	—	—	60.79	6.47	5.77	—1.64
		11—15	2.9	0.8	0.4	13.4	14.6	3.9	92	20	—120	—71.93	—5.34	—0.40	—1.43
		27—33	1.9	1.2	0.6	13.0	14.8	4.1	91	12	—100	—71.00	—6.11	—0.42	—1.99
		40—47	0.8	3.0	1.8	17.6	22.4	4.0	79	9	—370	—67.67	—7.28	—0.47	—2.13
225	Medium-strong podzolic on slate eluvio-deluvium	0—1	—	12.6	8.7	6.8	28.1	4.7	24	Not det'd.					
		2—8	—	1.4	0.1	3.7	5.2	3.7	71	"					
		13—19	—	0.5	0.2	—	—	4.1	—	"					
		35—40	—	0.5	0.2	4.9	5.6	4.3	87	"					
		52—57	—	0.7	0.3	8.5	9.5	4.2	88	"					
		63—68	—	0.8	0.3	21.1	22.1	4.0	95	"					
640	Medium podzolic on deluvial clay loam, Central Urals[b]	0—4	14.3	19.8	5.2	5.2	30.2	4.3	17	"					
		4—12	6.8	12.1	2.7	2.7	17.5	4.1	15	"					
		12—22	1.0	4.5	1.2	2.1	7.8	4.0	27	"					
		35—45	0.3	17.1	6.9	2.4	26.4	4.2	10	"					
		80—90	—	21.8	9.9	0.1	31.8	4.7	0	"					
		150—160	—	22.7	7.8	0.0	30.5	5.2	0	"					
201	Medium podzolic on marl deluvium	0—5	47.3	54.3	0.9	6.0	56.2	4.9	10	Not det'd.		70.75	6.41	4.24	2.51
		12—18	5.2	15.7	1.5	6.4	23.5	4.1	27	"		75.33	4.53	1.03	1.57
		22—27	2.7	11.9	1.8	5.4	19.1	4.6	28	"		76.12	4.66	1.01	1.58
		35—38	1.5	17.9	1.3	4.1	23.3	4.3	17	"		72.98	5.55	1.13	1.95
		40—45	2.0	28.1	1.4	2.8	32.3	4.3	8	"		69.91	6.40	1.42	2.40
		72—78	1.7	64.2	—	None	—	6.2	0	"		64.94	7.74	2.27	3.80

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[a] Ignition loss.

[b] L. A. Letkov's profile.

other methods for complete dispersion. There is also the possibility that the reason for the resistance of the parent material in relation to podzol-formation processes may lie in the stable aggregation of the clay fraction.

And so we see that in the formation of soils on eluvium of acid slates in the south of the podzolic zone the soil formation process takes a most unusual form: the soils have a number of original features which undoubtedly justify their distinction as an independent genus of the podzolic soils group. Characteristic features of this genus are:

1) Marked weak development of the sod process compared with soils which have developed in similar bioclimatic conditions but on parent material not having potential acidity. 2) High acidity and base unsaturation of the whole soil profile, including C horizon. 3) Large quantity of exchangeable aluminium which in a number of cases becomes toxic for crop plants. 4) Weak development of podzolic process, apparently because of inertness of colloidal part of soil.

Grey forest soils and chernozems. We observed the forming of grey forest soils and chernozems on parent material possessing potential acidity in Chita region. The parent material also consists of clay and chlorite slates. A salt suspension prepared from a pulverized fragment of the parent material showed pH in the interval 3.9-5.9. However, in contrast to the Ural parent material the Chita slates did not reveal large quantities of exchangeable (mobile) aluminium. Its quantity did not usually exceed 1.5-3.0 meq per 100 g of the material. As a rule, the amount of CaO in the total composition of these slates did not exceed 0.3%-0.5%. The quantity of MgO is always rather higher, but it seldom reached 2%-2.5%. The acidic reaction of this material is apparently associated with its low base-contents and hence its extremely low buffer capacity in the acid interval. Both are in our view conditioned by the character of the original material, layers of which formed the strata of the parent material (acid products from weathering and soil formation in ancient epochs).

Here is a morphological profile description of grey forest soil and chernozem developed on slate eluvium possessing an acidic reaction:

Profile No. 263. Chita region. Aginskiy district.[1] Slope of SE exposition, gradient 5%. Forest clearing. The ground cover contained: bluegrass, cinquefoil, koeleria, Galium, (cheese rennet) burnet, Dasyphora (Potentilla fruticosa).

A_0 0-5 cm. Cinnamon-brownish-grey coarse clay loam with gravel and crushed stone, moist. Unstable blocky-like structure.

A_1 5-24 cm. Cinnamon-brownish grey coarse clay loam including gravel and rubble, moist. Unstable, blocky-like structure. Clea transition.

B_1 24-40 cm. Grey-brown, with greenish grey tint (apparently due to presence of fine flakes of slate) Unstable, blocky structure. Transition to B_2 gradual.

B_2 40-58 cm. Brown-grey, mass of pare material rubble. Sparse whitish sprinklings noticeable.

BC 58-82 cm. Gravel and fine rubble of parent material.

C 82 cm. (bottom 147 cm). Rubble o parent material (weathered part of slate slab). Does not effervesce in HCl.

Profile No. 39. Chkalov collective farm, Chita region. Undulating relief. Profile on south slope. Gradient 7-9 degrees. Meadow steppe of grass and tansy.

$A_0 + {}_1$0-5 cm. Cinnamon-brown grey compact coarse clay loam. Many plant roots. Clear transition by compaction.

A_1 5-31 cm. Cinnamon-brown grey, the cinnamon-brown more clearly defined than in previous horizon, coarse clay loam including parent material rubble. Loosely compacted, in places even friable. Tongue-like transitio to underlying horizon.

B_1 31-58 cm. Brownish-yellow, with bro humus inlets, medium clay loam, compact, o casional slate rubble. Gradual transition to underlying horizon.

B_2 58-70. cm. Yellowish with greenish-gre tint, compact, medium clay loam with large quantity of slate rubble. Occasional plant roots. Transition gradual.

B_3C 70 cm. Grey slate marl with greenish tint. Very little fine earth. Basic mass (80% of horizon capacity) comprises rubble of parent material. Does not effervesce in HCl.

Table 2 gives analytical data for two paire profiles. The first two are of soils formed i birch-forest-steppe conditions in the Transbaykal area; the third and fourth give an idea of soils forming in the meadow steppe zone of the same region. Profile 39 and 263 typify soils developed on eluvio-deluvium of Paleozoic slates possessing acid reaction (3.9-4.3) and extremely low in calcium content (total C content 0.3%-0.4%). Profiles 103 and 84 also

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[1] Profiles No. 263, 39 and 84 described by N. V. Kuklin.

Table 2

Physicochemical characteristics of steppe and forest-steppe soils in Chita region

Profile No.	Soil	Depth, cm	Percent humus (Tyurin's method)	Adsorbed cations (Gedroyt's method)			Degree of base unsaturation	pH of salt suspension	Percent CO_2	Percent of particles <0.001 mm in diameter	Adsorp. capacity <0.001 mm diam. particles meq/100g	Total CaO and MgO content, % ignited soil	
				Ca + Mg	H	Total						CaO	MgO
263	Dark-grey forest on slate eluvium	0—5	8.2	28.8	1.4	30.2	4.5	4.79	None	16.1	180	1.9	2.1
		12—22	5.5	19.5	4.4	23.9	18.4	3.86	—	13.4	180	1.0	1.5
		28—38	1.5	7.0	4.0	11.0	36.3	3.68	—	5.3	200	0.5	0.9
		45—55	0.2	7.0	3.4	10.4	32.7	3.33	—	5.6	180	0.3	0.9
		70—80	0.1	6.4	1.5	7.9	19.0	3.33	—	4.1	190	0.3	1.3
		par. mat.			Not det'd.			4.26	—	—	—	0.3	2.6
103	Dark-grey forest on slate eluvium	0—10	6.6	18.3		Not det'd.		6.04	—	9.5	190	1.4	1.5
		10—20	4.9	24.6		"		4.52	—	9.2	269	2.0	1.3
		20—30	3.6	18.2		"		4.23	—	11.9	150	0.8	1.3
		30—40	2.8	16.2		"		4.50	—	12.3	130	0.7	1.0
		par. mat.			Not det'd.			6.78	—	—	—	1.3	1.3
39	"Black soil" on acidic parent material on slate eluvium	0—5	6.9	24.0	0.9	24.9	3.6	5.00	—	14.7	170	1.3	1.7
		18—23	3.6	25.1	1.2	27.3	4.3	4.07	—	11.6	240	1.1	2.0
		40—45	0.7	16.8	6.4	23.2	27.6	4.00	—	—	—	0.6	2.4
		62—68	0.4	13.5	2.1	15.6	13.4	3.31	—	10.5	150	0.6	1.9
		86—90	0.2	15.8	3.7	19.8	18.7	3.16	—	12.5	160	0.4	2.4
		par. mat.			Not det'd.			3.92	—	—	—	0.4	2.2
84	Black soil on slate eluvium	0—5	5.6	20.0	—	19.9[a]	—	6.50	—	12.9	160	1.2	1.7
		18—22	3.5	—	—	25.2[a]	—	6.23	—	12.8	200	—	—
		35—40	1.64	—	—	15.1[a]	—	6.95	—	7.4	200	—	—
		55—60	0.68	—	—	8.1[a]	—	7.00	6.5	3.9	200	—	—
		80—85	0.3	—	—	5.6[a]	—	7.29	2.7	3.5	160	4.4	1.9
		par. mat.			Not det'd.			6.32	—	—	—	1.2	1.9

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[a] Adsorption capacity determined by Babko-Askinazi's method.

represent soils developed on eluvium of slates, but having a higher pH-value (6.3-6.8) and containing rather more calcium. Their total CaO content amounts to 1.2%-1.3%, and MgO content to 1.2%-2.6%.

We now turn to the profiles of dark-grey forest soils. Comparing the analytical data for these two profiles we must bear in mind that there is no complete similarity between Profiles 103 and 263, although they are formed in the same bioclimatic conditions. Profile 103 has an underdeveloped, incomplete profile and is to a greater extent enriched with rubble of the solid parent material, i. e., it is at an earlier stage of development. This certainly complicates comparison of the data for these profiles, making it to a certain extent conditional. Nevertheless we have found it possible to compare a number of indices of the two profiles.

Looking through the analytical data for the dark-grey forest soils one is first of all struck by the very low pH-value in both profiles. The greatest acidity is naturally present in the soil formed on parent material with a low pH-value. Here, there is a clear increase in acidity with depth.

Extremely interesting, from our point of view, is the acid reaction of eluvio-deluvium compared to the dense parent material. We think that the primary reason for this is the extremely low content of alkaline-earth bases in the parent material itself. In the soil formation process the lower soil horizons become even more impoverished in bases as a result of the latter undergoing biological transposition into the surface horizons. Where the base contents are extremely low evidently even small quantities of acid bases are enough sharply to displace the mineral substratum's pH-value. In this case displacement of the pH could take place both as an effect of root secretion by plants and as a result of the appearance of even small quantities of unsaturated organic acids seeping down from the surface horizons.

One is struck by the fact that the strongly acidic reaction remains in the soil most persistently, even in the humus horizon (particularly its lower part), where there is already a clearly defined biological accumulation of bases. The amount of "adsorbed hydrogen" in these horizons does not diminish, although the degree of saturation with bases increases because of the sharp increase of adsorbed calcium. Despite the clearly acidic reaction the humus horizon in these soils is most sharply defined and the humus content decreases abruptly as the depth increases. The other process of humus distribution in Profile 103 we are inclined to explain by the primitive and underdeveloped nature of the soil concerned, and by its high content of rubble. As we know, a high humus content throughout the profile stratum is a fairly usual phenomenon when soils on stony substrate are at early stages of development.

It may be that the accumulation of humus in soils of this type is favored by the bioclimatic conditions peculiar to Eastern Siberia, involving delayed processes of decomposition of organic residue and an associated accumulation of half-decomposed products. The data relatin to group humus composition given in Table 3 indicate a high content of non-hydrolyzed residue (36% of the total quantity of humus). This confirms what has been said previously. It is also interesting to note that predominant in the group of humin acids and fulvic acids is the first fraction, i. e., the fraction consisting mainly of free organic acids and partially of acids associated with mobile hydroxides. The parent material is also doubtless exerting its influence here, for a high content of the second group of humin acids[2] is characteristic of dark-grey forest soils with a weakly acidic reaction. What it is that hinders the downward movement of organic acids through the soil profile is still not understood.

Finally, one is struck by the very high adsorption capacity of the clay fraction, even in low-lying non-humus horizons (130-190 meq per 100 g of clay). This, it seems to us, confirms our hypothesis outlined previously concerning incomplete dispersion of clay in analys of the clay formations of ancient epochs, which we are inclined to associate with their stable aggregation, and the resulting low activity of their fine fractions.

We thus see that dark-grey forest soils formed on acid parent materials have a numbe of specific distinguishing features:

1) Strong acidic reaction throughout the soil profile, C horizon being the most acid. 2) Few signs, or even complete absence, of podzolization, the presence of which is a characteristic feature of this group of soils. 3) Predominance of free organic acids in composition of humus.

As we see, the specific features of the soils concerned are so significant that one begins to doubt whether it is enough to reflect them in th genus category, or whether they should find reflection in a higher taxonomic category withi the group of grey forest soils.

Let us examine the data for soils of steppe territory.

In these soils one is first of all struck by th relatively thin humus horizon and its low humu

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[2] M. M. Kononova. 1951. The problems of soil humus and contemporary tasks of its study. Published by USSR Academy of Sciences, Moscow.

Table 3

Group composition of organic substance of steppe and forest-steppe soils

Profile No.	Depth, cm	% humus (Tyurin's method)	Humin acids			Fulvic acids				Nonhydrolyzed residue	C of humin acids / C of fulvic acids
			I	II	III	Ia	I	II	III		
39	0—5	6.9	9.2	16.0	3.4	3.7	10.8	3.7	4.7	37.8	1.2
	18—2.	3.6	8.2	13.6	2.5	4.7	12.7	12.5	7.5	24.8	0.6
84	0—5	5.6	1.2	19.9	10.5	0.0	0.0	17.9	6.9	29.7	1.3
	18—22	3.5	1.4	21.2	8.5	0.0	0.0	20.2	5.8	28.4	0.9
263	0—5	8.2	16.8	8.7	3.6	4.3	8.0	11.8	6.7	36.3	0.9
	12—22	5.5	14.3	10.6	3.4	6.4	7.1	22.4	4.7	31.4	0.7

ontent. This is one of the provincial features f Transbaykal chernozems.[3]

Comparing the data for the two profiles the rst thing we note is the sharp difference beween them. The strong acidic reaction in rofile 39 which, as we know, is not characterstic of steppe zone soils, seems particularly trange. The degree of acidity rises distinctly s the depth increases, and it is again the lower orizon that is the most acid. There is no doubt hatever that this is connected with the charcter of the parent material. Acidic reaction nherited by soil from the parent material radually becomes normal in the upper horions during the soil formation process as a esult of the biological accumulation of bases. owever, their low content in the parent marial slows down the intensity of this process, nd the soil, despite what would appear to be vorable bioclimatic circumstances, remains cid even within the humus horizon. We find lack of correspondence between the high degree f base saturation (96.4%) and the pH-value (pH f salt suspension 5.0).

The picture with regard to the forming of oils on parent material having a neutral rection and a higher calcium content is quite ifferent. The upper part of the profile of ese soils has a neutral reaction; the lower as an alkaline reaction. At the same time ere is a movement of calcium bicarbonate olution along the profile and a horizon enched with its carbonates is formed. Hence, this case what happens is the formation of chernozem profile typical of the Transbaykal.

The high content of calcium carbonates in dividual horizons of Profile 84 with relative- low content in the parent material forces s to assume that their accumulation at this articular point is not only due to weathering and soil formation but that it takes place also because of the transfer of calcium from the upper parts of the slope in which the profile lies. It is also very probable that the large quantity of calcium carbonates may be a result of the gradual removal of decarbonated surface horizons by centuries of denudation processes and the drawing up of fresh rock horizons into the stratum of soil formation and intense weathering. We cannot assert on the basis of our data that in steppe zone conditions one percent of the total CaO content in the parent material is enough for the chernozem soil formation process to take its normal course. In this case we confine ourselves to comparing the profile of a fairly characteristic Transbaykal steppe chernozem soil with a steppe soil developed on a parent body possessing an acidic reaction and extremely deficient in alkaline-earth bases (largely Ca).

The two profiles are similar as regards q quantity of humus in the upper horizons. The rather smaller quantity of humus in Profile 84 is evidently connected with the coarser textured soil. The impression is that the difference in the pH-value of the surface horizons of these soils does not substantially influence the accumulation of humus.

One is struck by the rather smaller thickness of the humus-enriched horizon, and its more abrupt lower boundary in soil developed on acidic parent material (which to some extent makes it resemble the dark-grey forest soil of Profile 264).

The data for group composition of organic substance (Table 3) shows that in both the steppe soil profiles it is fraction II, i. e, humin acids associated with calcium, that predominates in the composition of the group of humus acids, whereas in Profile 263 it is the first fraction that predominates, the pH-values being similar. With the litter decomposition of steppe associations, there is evidently enough calcium in the residue to link most of the aggressive, highly mobile forms of humin acids. In these conditions, therefore, the humus does not display great downward mobility in the soil profile. The ratio of C humin acids to C fulvic-acids is also identical in the upper horizons of both profiles. At the same time, however, even the humin acids behave differently in the profiles given. In the chernozems of the normal profile, fraction I of the humin acids is very small, whereas in Profile 39 it amounts to 8%-9%. These soils also differ as regards the quantity of nonhydrolyzed residue (as far as these indices are concerned Profiles 39 and 263 begin to resemble one another to a certain extent).

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[3] As this problem is not part of this article's eme we shall allow ourselves not to dwell on it.

Summing up the material on steppe zone soils developed on parent material having an acidic reaction and a very low total content of alkaline-earth bases, we can state that these soils have a number of features which distinguish them very substantially from the soils of the chernozem group:

1) Acidic reaction of the whole profile and particularly its lower part; 2) Absence of calcium carbonates in the soil profile; 3) High content of nonsaturated, free organic acids in composition of the humus; 4) Very narrow ratio of C humin acids to C fulvic-acids in the lower part of the humus horizon.

It is our belief that the specific features we have indicated of soils developed on parent material having a very low content of alkaline-earth bases (mainly calcium) are so significant and so incompatible with the established parameters of chernozems that it is pertinent to raise the question of the impossibility of assigning them to the chernozem group. It would perhaps be more correct as far as the steppe zone is concerned to distinguish a grou of acidic steppe soils — following the analogy of the group of "soddy-carbonate soils" which, as is known, are a lithogenous formation withi the general region in which soils of the podzoli group are to be found.

Conclusions

1. In classifying parent materials forming soils it is necessary to make a particular distinction in the case of the group of materials which have a very low content of alkaline-eart bases and an acidic reaction; the influence of these materials upon soil formation processes in different soil-climatic zones in both very great and highly singular.

2. In studying the genesis of different types of soils greater attention must be paid to the influence of the parent material. In many cases this will not only enable the different properties of the soils to be evaluated more correctly but it will also enable the relict, residual soils to be separated from what has b acquired in the process of recent soil formatio

3. The classificational position of soils formed on parent materials deficient in alkalin earth bases must be defined from the zonal poi of view.

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BOGS AND PEATS OF NORTH AMERICA

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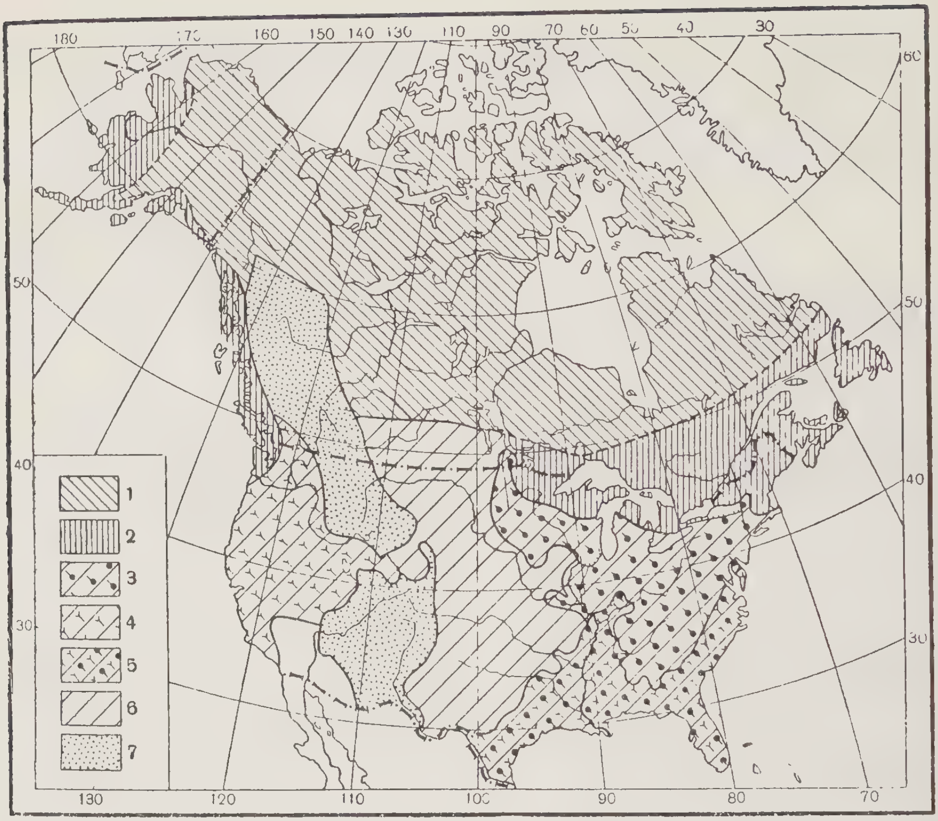
North America is rich in bogs and peats. Their geographical distribution is most peculiar, s are the types of bog and their flora. There is uite an extensive literature on the subject: here is a general work for the USA (5); a num-er of articles outline the patterns governing he distribution of bogs in the USA and Canada. Rigg's articles (19, 20) provide information on ogs in various areas, but there is no general ccount and map of types of bogs for the whole ontinent. We shall endeavor to fill this gap n the present article. The author's acquain-ance with bogs in many parts of the USSR and he great similarity in the general distribution f bogs in the USA and Eurasia have made it ossible to unify the often sketchy descriptions or North America, with interpolated refer-nces to the "white spots" so abundant in Canada. The map published by me earlier (2) is repro-uced in the article with some minor altera-ions. In view of the shortness of the article nly a few of the hundred or so works used are isted. Because of shortage of space the arti-le mostly describes only bogs in plains, and hen only those characteristic of the area on which they are in the concluding stage of de-elopment.

Distribution of Bogs and Peat-marshes. In he northern continent surface swamps are widespread in the permafrost region, and an rganogenic layer, generally not exceeding 0 cm thick, covers large areas. Peats are carce here. In southeast Canada and the djacent part of the USA the climate is condu-ive to peat formation. There are large ac-umulations of peats in the plain areas — in the t. Lawrence lowland and in the region of former lakes of the late glacial period (Algon-uin, Agassiz), of which the Great Lakes are elicts. In the central USA, in the prairie and rid areas, the droughty climate hinders peat ormation. For this reason, and also because f the mountain ranges, the peat formation belt n America is not continuous, as it is in Europe nd Western Siberia, but is interrupted in the enter of the continent. In Eastern Canada, wing to the cooling influence of the Polar sea which dips deep into the continent, this belt — and the tundra with it — sweeps further south than anywhere else in the world. On the west coast, on the other land, melt-water of peats stretch north beyond the polar circle.

The dryness of the climate in the center of the continent is due to the fact that the moist Pacific winds are held up by the coastal mountain ranges, while the eastern winds, despite the absence of mountain ranges on the east coast, do not penetrate deep into the continent (1). The abrupt changes in temperature following the free exchange of air masses from the north and south are an additional factor for unfavorable peat formation. In the center of the continent, for instance in Ohio, peats do not for the most part extend beyond the limits of the Wisconsin freezing zone, although, as we have seen previously, large accumulations of them are to be found far to the north of the zone. In Eastern Europe on the other hand and in Western Siberia extremely swampy forest regions do extend south to these limits. However on the coastal plains of the Atlantic and Mexican Gulf large bogs and peats descend into the subtropical latitudes. This is explained by the relief of the plains and the high level of soil waters in this arid zone, and also by the abundant precipitations wind-borne from the Mexican Gulf. Large peats also stretch far to the south along the alluvia of the Mississippi. Their formation was due to river flooding. In general, the large expanses of tundra, steppe, desert and mountain ranges considerably reduce the percentage of the peat areas in North America as compared with Europe and Western Siberia. A rough estimate would put the peat areas in the USA (excluding Alaska) at 0.4%-0.5% of the whole territory; in Canada (not including unexplored provinces) at 1.0%-1.2%, and in North America as a whole at 0.7%-0.8%. Europe's peat areas are about 5.5%.

Flora of Bogs. The dendroflora of North America does not have species in common with Europe. There are however a number of species among the shrubs, and particularly among the



1 - Bogs in territories with permanent or insular frost, i.e., bogs on tundra plains, in areas where trees are sparse, and in the north of the forest zone and in mountain valleys. Surfaces of bogs deformed by frost. Vegetation of lower parts usually mesotrophic or eutrophic, also oligotrophic further south. Trees, if any, as a rule only coniferous; 2 - Oligotrophic sphagnums, including raised bogs or similar. Vegetation in bog center on higher areas and in depressions is oligotrophic. In drier areas coniferous trees grow, either singly, in groups or forming stories; 3 - Eutrophic forest bogs with wide variety of broad-leaf trees; 4 - Tall-grass bogs, subject to flooding, in deltas, and river valleys, in mountain valleys and hollows near lakes. Solonchaks also found; 5 - Eutrophic forest bogs with tertiary tree species, mainly *Taxodium* and *Nyssa*, and also tall-grass bogs. Saltwater bogs, including mangroves (in south), frequent along coast of ocean, and also Mexican Gulf; 6 - Territories with few bogs, which are of the eutrophic type; 7 - Largely mountainous areas. Bogs on ridges, slopes, and in valleys and hollows.

stunted woody plants (shrubs), growing in the bogs of North America, which are encountered in Europe. The flora of the bog mosses, especially sphagnums, is also similar to that found in Europe. It is only in the southeast of the continent that the number of spagnum types not found in Europe increases. The northern bogs, particularly the oligotrophic spagnums, most closely resemble the raised bogs of Europe insofar as their species are concerned — except for trees. As for the sphagnums, their species are the same as in Europe. Further south, forest bogs with broadleaf trees and with swamp cypresses have not only species, but many genera and even certain families which are foreign to Europe. Some components of these bogs have related species and genera which have completely died out in Europe, but which are encountered here in tertiary deposits. The ancient character of the flora of such bogs is a heritage of the distant past. In Europe and Siberia these features were obliterated as a result of the invasion of the boreal flora with the cooling of the climate at the end of the tertiary period.

Bog Zones and Provinces. We differentiate here between bog zones, which extend latitudi ously and provinces, which extend in a differe direction. The numbering of both is concerte with the map.

Bog Zones with Permafrost. The shallow permafrost, constituting a water barrier, giv se to extensive bogginess and deforms the rface of the bogs. The peat layer however eldom exceeds a few dozen centimeters in epth. The deformations give rise to the same nenomena as in Northern Eurasia. In the orth of this zone, polygonal-ridge bogs with ssures running deep into the frozen bed are ommon. They are formed over buried ice edges, have redges of peat along the sides nd fringe the normal swampy polygons and etragons. In the more southerly regions of ne zone, along the coast of Hudson Bay and in orthwest Alberta, bogs with peat hills frozen nside them are found — similar to the large-lled bogs of Eurasia. Hilly bogs are usually terspersed among bogs of another little-udied type (muskeg and others). Between em and the polygonal-ridge bogs there are ansitional formations imilar in type to the ssured-hilly bogs of Eurasia.

Provinces of Raised Bogs. South of the zone frozen bogs oligotrophic sphagnum bogs are und which are devoid of permafrost. Ameri-an investigators distinguish raised sphagnum gs and flat bogs, which are also often spagnum gs. Later we shall be dwelling on the former, r they are particularly characteristic and present the concluding stage of bog develop-ent. The raised bogs are to be found where ecipitations exceed evaporation. They do ot form a continuous zone, as in Europe, but e divided by prairies and mountain ranges to two provinces — Atlantic and Pacific. We all preface a description of these provinces ith some data bout the flora of raised bogs. orth America is extremely rich in tree and rub species. These differ strongly in the st and west of the continent; in the east we stinguish boreal coniferous forests and the rests of the Great Lakes region, and in the est "coast forest." This is also reflected in e flora of bogs in the two provinces (16). The ees most frequently found in bogs in the east e black spruce (Picea mariana) and larch arix Americana). In the Great Lakes country ey are joined by Tsuga candensis, Thuja oc-dentalis, Chamaecyparis thyoides, and pines inus banksiana, P. strobus). Other species owing only in bogs in the east are: Cassandra lyculata, Kalmia angustifolia, Chiogenes Lis-dula, Simplecarpus foetidus, insectivorous rracene (Sarracenia purpurea), cranberry accinium macrocarpon) (in the more souther- states), and others. The trees in bogs in the est belong to other species of the same genera: ne Tsuga genus is represented by Tsuga mer-nsiana (in Alaska) and T. heterophylla (in more utherly areas); spruce by Picea sitchensis; uja by Thuja plicata; and pines by Pinus ntarta. These species are also joined by seudotsuga taxifolia. A number of species of rubs and grasses grow both in the west and e east: marsh rosemary (Ledum groenlandi-m), Kalmia polifolia, cranberry (Oxcoccus lustris), crowberry (Empetrum nigrum), cloudberry (Rubus chamaemorus), Rhynchospora alba, Drosera rotundifolia, D. anglica and others. Many in this group of species are common in bogs of the boreal region of Eurasia.

Atlantic Province of Raised Bogs. This province begins north of the 40th parallel and extends along the coastal plain to southern Canada. In the west it covers the Great Lakes region as far as Minnesota. Because of the rich peat deposits in this region and the St. Lawrence Lowland the peat incidence throughout the whole province is very considerable. Raised bogs change in character both from south to north, and from east to west. At the southern edge of the raised bog zone (New York) the oligotrophic bogs are flat. They lie in deep hollows in the locality of former lakes, and are fully or partially peat-covered. They are wet, and often consist of quagmires with a continuous sphagnum top-layer, with growths of Cassandra and coniferous trees along the edges (13). Further to the north, in central Maine, real raised bogs are to be found (5, 13). Their degree of protuberance reaches 4.5-6.0 m, and the thickness of slightly decomposed sphagnum peat is in the region of 5 m. The Sphagnum fuscum cover is luxuriant, but the trees and shrubs are very stunted. The height of the former when well grown is sometimes no more than 0.6 m, and of the latter 12-17 cm. However, shrubs do predominate over grasses. Northern species occur — cloudberry and crowberry.

Below the sphagnum lies woody peat; below that grass-sedge peat, and sometimes even gytja (muck). Further north, in Brunswick (3, 8) the peats are also well raised; they have thick upper layers of sphagnum peat. But here the bogs have steep slopes along the edges with a gradient of from 1:11 to 1:3 and a more or less horizontal plateau where the water becomes stagnant and moisture-loving sedges — Eriophorum vaginatum and Scirpus caespitosus — often predominate over shrub. The northern cloudberry and crowberry are more abundant here than in Maine. Sphagnum fuscum is joined here by Spagnum rubellum. Further to the east (Nova Scotia, Cape Breton) (12, 13) peats are found not only in hollows but on raised and undulating forms of relief. This is possible where high air humidity permits peat formation on slopes. However the cold climate here limits peat accumulation. The thickness of the spagnum peat and the degree of protuberance is therefore less, and in Nova Scotia even flat sphagnum peats are no rarety. Trees are extremely stunted and gnarled — on Cape Breton there are 50 year-larches only 30 cm high. The bogs are very wet, and often have numerous small lakes. Scirpus caespitosus is abundant. Sphagnum fuscum is partially replaced by Sphagnum rubellum. Of the coastal species Sphagnum imbricatum predominates, and on Cape Breton the moss species Rhacomitrium lanuginosum is found. In general, moving from New York to Nova

Scotia, the protuberance of the bogs and thickness of the sphagnum peat at first rises, then falls away. Bog formation of dry land increases as a result of ponding of water. Bogs in hollows give place more and more to bogs on slopes and relief protuberances. The water content of bogs increases, with the role of shrubs diminishing as a result and that of moisture-loving plants increasing. The role of northern species (cloudberry, crowberry) and of species peculiar to the cold coastal climate (Sphagnum imbricatum, Scirpus caespitosus) increases. All these changes depend upon increased moisture and lower temperatures. Peat ridges are apparently less developed in bogs of the coastal province than in northern Europe, probably because of the lesser extent to which the bogs here are frozen through. Moving inland from the coastal area to the west, the bogs become less protuberant as the continental mass increases, the role of sedge peats increases in relation to sphagnums, that of shrubs in the vegetation grows, and the coastal raised bogs in Minnesota are replaced by flat sphagnum peats of the continental type.

Pacific Province of Raised Bogs. The province occupies a narrow coastal belt from Washington to Alaska. Bogs are found here in the lowland coastal regions, neighboring islands, coastal mountain valleys and here and there on plateaus. In Washington State oligotrophic sphagnum peats are encountered in the broad trough-like valleys parallel to the ocean, and nearer to the ocean along the Columbia River. Bogs also occur in plateau depressions. According to Dachnowsky-Stokes (5) the tree canopy develops in the sphagnum peats in the concluding stage of development consisting of Thuja plicata and Tsuga heterophylla, with an admixture of Pseudotsuga mucronata and Picea sitchensis. Under the trees is a story of shrub — marsh rosemary (Ledum groenlandicum) where the trees are thicker, and Kalmia polifolia where they are sparser. The sphagnum toplayer is formed by Sphagnum fuscum and other species. Towards the outer edges of the swamp, bog-myrtle (Myrica california) and other shrubs are to be found. These bogs are of the shrubby-sphagnum type, with a partial tree canopy. Surface protuberance is noticeably small. The upper stratum of sphagnum peat has an acidic reaction, and is not usually more than 1.8 m deep; but sphagnum peat of quagmire origin can reach a depth of 6 m. Below the sphagnum peat, woody peat 0.25-0.6 m thick is sometimes found; below that a rushy peat (2.4-2.8 m), and then gyttja (muck) (0.9-7.8 m). The peats here are commonly found in the water ponds and in volcanic cones. In Washington State 325 peat areas covering more than 20,000 ha have been studied. They are not large: only nine of them are larger than 400 ha and only one 1,400 ha (21). In British Columbia peats are concentrated mainly on Queen Charlotte and Prince Rupert islands, in the north of Vancouver island, and particularly on the Frazer River lowland, as described by Osvald (14). In this region they are to be found mainly on the deposits of the Frazer delta. The largest peat-bog is over 10,000 ha in size and protrudes to a height of 3.6 m. The others ar smaller and protrude little. All are peats of the continental type, as are those in Washingt and have Ledum graenlandicum. In the topsoil layer lichens predominate in the middle of the bogs and the moss Pleurozium Schreber around the edges. Sphagnum fuscum plays a subordinate role, probably as a result of fires Tsuga heterophylla and Pinus contorta are common tree species. Osvald's diagram show a deposit structure similar to peats in Washington. The upper stratum of sphagnum peat is split by a layer of strongly decomposed pea Below the sphagnum lies a woody peat, then sedge, and finally gyttja (muck). The bogs on the islands near the southern end of Vancouve island closely resemble those of the Frazer delta in vegetation and structure (14). Furthe north, bogs are widespread on the Queen Charlotte islands (10). In addition to the types of trees listed previously, Chamaecyparis nootkatensis and Tsuga mertensiana are also to be found here. The list of plants includes Scirpu caespitosus, which is characteristic of bogs in cold and moist climates. These bogs are usu sphagnum at the top, with a thick layer of sph num peat. They include raised and flat peat-bogs, and also bogs with a sloping surface (bo on slopes). Further to the north, in the bogs of Alaska, the features deriving from the moi cold climate stand out still more sharply (see descriptions [6, 18]). As regards form of surface, the Alaskan peat-bogs have the same three varieties as those on the Queen Charlott islands. Raised bogs are known in the Junea area, between Seward and Hope, and in the inland regions. Characteristic examples of this type have a protuberance formed from growths of sphagnum peat. The latter, with a general peat-bog depth of up to 5.4 m, form a large part of the deposit. In other cases th origin of this sort of protuberance is differen The species of trees are on the whole the sam as in the Queen Charlotte Islands, and Scirpu caespitosus is a characteristic plant as it is there. The variety of bogs in Alaska reflects the variety of relief and climate in different parts of the country. In general, bog flora in Alaska is apparently richer than that in the coastal regions further south. The flora and other characteristics of bogs change over the intermediate expanses between Washington an Alaska. The comparatively dry, shrub, spha num bogs of the south are replaced, as we m north, by wetter bogs, where there are fewer shrubs, but where moisture-loving grasses, mainly sedge (Scirpus caespitosus, and other are more abundant. At the same time the rol of northern species increases. Thus, Empetr nigrum, abundant in Alaska and rarer in British Columbia, occurs only sporadically i

Vashington, but it does reach as far south as regon. Cloudberry (Rubus chamaemarus) s common in Alaska and British Columbia, ut is not found further south (18). The same "Northernism" applies to sphagnums. The orthern species Sphagnum lenense and S. ngstroemii are found only in Alaska and the ukon; the northern Sphagnum Lindbergii xtends south only as far as Vancouver. As he flora changes, so does the position of peat-ogs in the relief, their genesis and strati-raphy. The southern bogs in hollows, of vater pond origin and having a low-lying ayer of gyttjac (musk), are to a great ex-ent replaced in the north by peats of dry types ocated on slopes and even with protuberant re-ief forms. Similar changes from north to outh can be seen on the Atlantic coast (see bove).

Province of forest eutrophic bogs with abund-nce of broadleaf tree species. The northern nd northwestern limits of the province (map) ie along the boundary of the continental sub-roup of mesotrophic bogs (5). Dachnowskiy-tokes considers the bogs to be mesotrophic, but ince the peat reaction varies from slightly acid o slightly alkaline, and the ash content of the eats is considerable, it is better to call these eats eutotrophic. In the last stage of develop-nent the peats in the area become overgrown by rich variety of broadleaf deciduous trees. In ther cases the latter are joined by coniferous ypes. Remnants of these are abundant in the pper layer of the peat, which indicates that leciduous types have replaced coniferous ones. 'his change is becoming more marked at the resent time in connection with the intensive raining of the peats. The tree story in the bogs s formed mainly by maple (Acer rubrum), elm Ulmus fulva, U. americana), and ash (Fraxinus igra, F. americana). These are joined by valnuts (Juglans nigra, J. cinerea), hickory Carya condiformis), certain oaks (Quercus bi-olor), tulip tree (Liriodendron tulpifera), mag-olia (Magnolia acuminata) and certain others; nd of the coniferous type, by larch (Larix mericana), Thuja occidentalis, Tsuga cana-ensis and pine (Pinus strobus). Shrubs are umerous: several species of viburnams Viburnum), a number of species of Vaccinium, lum (Prunus virginiana), elder (Sambucus anadensis), buck-thorn (Rhamnus alnifolia), urrant (Ribes floridum), Caylussacia dumosa, nd many others. Sometimes instead of shrub, racken is abundant — King fern (Osmunda egalis, O. cinnamomea). The upper layer of ne deposit bed is formed by woody peat from oniferous and deciduous species. Its thick-ess is 0.6-1.2 m. Below that lies sedge and eedy peat — 0.45-0.9 m — and then gyttja muck). Sometimes the latter is absent, and ne sedgy and reedy peat lies on mineral soil n a lower layer of woody peat. Peats of this ype are found in Indiana, Ohio, Michigan and 'ew York (5). In New Jersey forest peats comprise 25% of the total peat area — 120,000 ha. Forest-type deposits predominate in the southern part of this state on the coastal plain. The turf is acidic, with pH-values of 3.8-5.5 and ash content of 3%-20% air-dry substance. There are no bogs of this type in Europe.

Pacific Province of tall-grass bogs. Bogs of this type are known in the area of San Francisco and Puget Sound (Washington state). In the former area there is 43 sq km of peat in the Sacramento and San Joaquin delta, which is criss-crossed by many tributaries. The alluvial and lake deposits below the peats contain alkaline salts which migrate in dry wheather into the upper layer of the peat bed. Below the upper rush and reed peat, which is 1.5-4.8 m thick, lies gyttja (muck) peat (-0.5-4.5 m). The whole stratum is 7 m thick. The peat has been cultivated, and the former vegetation now exists only in places. It consists of reeds (Scirpus lacustris, V. occidentalis, and other species), cane, with an admixture of bulrush (Typha latifolia) and others. In Puget Sound, bogs are situated in a wide mountain valley which is periodically flooded. Like the bogs near San Francisco, they have reeds and cane, but also sedge and water plants. However the peat here is acidic, fairly rich in iron, but it contains less alkaline salts and alkaline-earth metals. At the top the peat is reed and cane or sedge and reed, with a depth of 2.1-2.4 m, and below that it is of gyttja (muck) (up to 10 m). Here and there seams of peat containing coniferous woods are found. The cultivated peats near Lake Clemes, like other bogs in southern Oregon, probably have the same structure.

Province of forest bogs with swamp cypress (Taxodium Nyssa) and other tertiary tree species. This province coincides with the region where the swamp cypress is to be found and also with the coastal and Mexican Gulf coastal plains. It also includes part of the alluvial plain of the Mississippi. The characteristic feature of the province is forest bogs with tertiary species. These bogs are part of the intricate bog complexes, often enormous in area, where an important role is also played by various tall-grass bogs. Thus in the south of Florida, of 3.6 million ha of bogs, 48% is of the forest, including Taxodium, type of bog, 25% are tall-grass freshwater bogs ("Everglades"), 10% are saltwater marshes and "wet prairie" (7). The Everglades consist of growths of Mariscus jamaicensis (47%), wet, spongy areas and forest islands (30%), calcareous marshes (12%) and other types. In Louisiana, alluvial bogs along the Mississippi and other rivers cover 34 million ha (15). Of this area salty coastal bogs cover one million ha, freshwater grassy bogs 0.7, periodically flooded forest bogs 1.1 and permanently wet bogs (swamp) 0.6 million ha. Over and above these 3.4 million ha there are 0.6 million ha of water ponds with water vegetation. The vegetation of these bog complexes lies in belts. In coastal complexes the belts extend along the ocean shore, with the saltwater bogs nearer the ocean. In the south (Florida) they will be of the mangrove variety, and in North Carolina and Connecticut communities including various species of Spartina and other halophytes are found. In alluvial complexes the belts generally run parallel to the river.

The directly active ecological factors governing the formation of the belts are: 1) Hydrological factors — intensiveness of flooding, depth of soil waters, stability of water regime. 2) Content and composition of salts. This factor is important in coastal complexes. Forest bogs with swamp cypress are periodically covered with water. Fluctuations of level from 0.75 m above the surface of the soil to 0.3 m beneath it have been noted. Different communities of forest bogs have in their turn different water regimes. Where flooding is more intense the tree canopy is formed from Taxodium and Nyssa aquatica; where Nyssa biflora is also present the water level is lower. Where the level becomes lower still Taxodium and Nyssa are replaced by broadleaf species; this is particularly noticeable where there is drainage. Character of substratum, acidity and other adaphic factors differ strongly in different types of bogs. The well known "Dismal Swamp," which extends along the ocean shore from Virginia to North Carolina is a peculiar subtropical raised peat-bog (5). The peat reaction is sharply acidic. The central part of the peat area is 6.8 m higher than the edges. In the deposit bed one finds alternate layers of woody and gyttja (muck) peat, with a general thickness of 2.7 m. Of the woody peats the most common is swamp cypress. A second type is composed of remnants of Nyssa. A third is a mixed woody peat consisting of Chamaecyparis thyoides, Pinus taeda and evergreen shrub. Extensive peats in southern Florida also have raised surfaces. The deposit bed is often triple-layered: between an upper and lower layer of "sawgrass" (Sawgrass — Mariscus jamaicenais) lies a layer of gyttja (muck) peat. The thickness of the peat in places is more than 4 m (5). However, unlike the "Dismal Swamp" the peat reaction fluctuates between neutral and alkaline, and there are no woody peats, at least in the Everglades. In many cases forest bogs with Taxodium are not peat-bogs. Either the peat layer is very thin or the soil is mineral — ignition loss amounts to 22%. The vegetation of forest bogs is extremely varied depending upon the degree of water content, density of the tree canopy and the extent to which its habitat has been disturbed. In places where trees have grown densely in the past, three crown stories can be distinguished: the first, formed by Taxodium distichum, being 33 m tall; the second by Nyssa silvicata, and the third by Nyssa biflora, being 23 m tall. Apart from these three species the community has only nine different types of trees and shrubs, including liana. The canop of low trees and shrubs is weakly developed. There are fourteen species of herbaceous flora, all of them water species. The only on that is really abundant is duckweed which entirely covers the shady surface of the water, a certain redweeds. The large areas of shade account for the small numbers of shrubs and herbaceous species. In other cases there is a large number of tree and shrub species — 2 There is not a great variety of herbaceous flora (15 species). Where the upper canopy is not so dense and where the soil is less damp t following tree species appear in addition to those listed: Acer rubrum, Fraxinus pennsylvanica, Magnolia virginiana, and a number of others. Liana here grows as high as the treetops. Trunks have growths of the epiphyte bracken Polypodium polypodioides. Shrub species are numerous. It is interesting to no that these bogs with tertiary tree species are situated on habitats which have been recently formed on sea terraces and river alluvia. It is only in such conditions that these species a able to compete with the broadleaf types. Whe conditions become stabilized and change in the direction of dryness the tertiary conifers will be crowded out by the broadleaf species.

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EFFECT OF LIMING ON THE FERTILITY OF ACID SOILS IN ESTONIAN SSR

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In 1946 we began research with a view to ascertaining the usefulness of liming as a means of increasing soil fertility in Estonia. The first field experiment was established at the experimental farm of the Estonian Agricultural Academy (at that time Tartu State University). In the next three years a series of field experiments was started in six districts in Southern Estonia (Tartu, Pyl'vaskiy, Ryapinaskiy, Vyruskiy, El'vaskiy and Vil'yandskiy). The purpose was to establish optimum amounts of lime fertilizer, using quarter, half, normal, one and a half and double quantities taking hydrolytic acidity as a basis. The number of replications was four, and the area of plots under study was 100 sq.m. In all, 23 experiments were conducted at collective state, and experimental farms in the district named. Of these, nine areas still exist where a record of yields is kept and the soil's chemical properties are studied. The following are determined: pH in an extract of potassium chloride, hydrolytic acidity, content of exchangeable bases, and, on the basis of the last two, the degree of saturation.[1]

The experiments were carried out on land used for general purposes, and the agricultural techniques and crops cultivated were therefore exactly the same. At first identical quantities of organic and mineral fertilizers were applied by the farms concerned to both the experimental area and the rest of the field. These experiments were not sufficiently accurate, and in recent years the experimental areas have been separated from the field as a whole and the fertilizers have been applied by members of the Soil Science and Agricultural Chemistry Department of the Estonian Agricultural Academy.

As we cannot deal with the changes that have taken place in the soils of the separate experimental areas, we shall give only general information about the changes in the chemical properties of the soils over the eight years since the experiment began.

From Table 1 we see that even a quarter amount of lime considerably changes both hydrolytic acidity and content of exchangeable bases. The increased content of the latter in the limed soil is, at the beginning of the exper ment, almost proportional to the quantity of lime used. No such proportionality was to ha been expected in the reduction of hydrolytic acidity, and small amounts of lime bring about comparatively large changes. If quarte half or full amounts of lime are applied, hydrolytic acidity declines during the first four years. But from the fifth year onwards the difference in hydrolytic acidity between limed and non-limed soils gradually begins to dimin Nevertheless, even in the eighth year after liming this difference is not less than it was i the first year after liming. With the same amounts of lime the content of exchangeable bases increases in the first four years. Here too, from the fifth year onwards, their conten in the soil slowly decreases. In the eighth year after liming the content of exchangeable bases is not less than in the first year.

When double amounts of lime are applied the hydrolytic acidity and content of exchangeable bases change in a different way. The dif ference in hydrolytic acidity increases up to the fifth year after liming. Thereafter it sho a tendency to decline. The content of exchang able bases reaches a maximum in the second year after liming; then there is a comparative sharp reduction. As for the degree of saturation, this too rises until the fourth year after liming. In the next three years it declines somewhat, but again rises in the eighth year.

In order to determine the agrochemical indices soil test samples have in recent years been taken not only from the arable layer (0-2 cm), but also from the sub-arable layer (20-4 cm). Table 2 gives the average changes of th indices as regards both layers for the eighth

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[1] In the period 1950-1953 analysis was carried out under the author's supervision by graduate student Talpsepp (3).

Table 1

Dynamics of change of average chemical indices in soil after liming

No. of years after liming	Liming according to hydrolytic acidity											
	0.25	0.5	1.0	2.0	0.25	0.5	1.0	2.0	0.25	0.5	1.0	2.0
	Increase of exchangeable bases content (S), meq				Reduction of hydrolytic acidity (H), meq				% increase of degree of saturation (V)			
1	0.95	1.55	2.98	7.08	0.53	0.73	1.10	1.78	10.1	14.4	22.6	36.9
2	0.79	1.30	3.45	8.03	0.71	1.02	1.53	2.14	8.7	14.2	24.6	35.8
4	1.55	2.16	3.62	7.33	1.35	1.33	1.98	2.27	18.0	19.4	27.5	37.9
5	—	1.41	2.89	6.54	—	0.93	1.52	2.69	—	10.8	17.8	30.6
7	0.91	1.76	2.66	5.08	0.42	0.60	0.82	1.30	9.3	23.6	17.9	26.1
8	1.26	1.79	2.96	5.44	0.44	0.81	1.09	1.55	12.3	18.5	25.3	34.1

Table 2

Differences of chemical indices of limed and non-limed soils in eighth year after liming

Liming according to hydrolytic acidity	Plowed layer, 0-20 cm			Sub-soil layer, 20-40 cm		
	(S) increase, meq	(H) reduction, meq	% (V) increase	(S) increase, meq	(H) reduction, meq	% (V) increase
0.25	1.27	0.44	12.3	0.62	0.23	8.1
0.5	1.51	0.66	14.7	0.58	0.29	8.3
1.0	2.63	1.10	23.8	0.77	0.62	14.0
2.0	4.68	1.58	32.9	1.52	1.07	24.4

ear after liming.

From Table 2 we see that in the plowed ayer quarter amounts of lime cause compar- tively large changes in hydrolytic acidity and egree of saturation. In the subsoil both quarter nd half amounts of lime cause practically dentical changes in both these indices. In art this applies also to the content of exchange- ble bases. In this case plowing brings about partial intermingling of the limed layer and e sub-soil. However the increase in the ontent of exchangeable bases together with e decrease in hydrolytic acidity when larger mounts of lime are applied is so considerable at there are grounds for concluding that partial eaching of the lime in the subsoil takes place. should be noted that, from the initial half mount of lime, an almost linear change of emical properties also occurs in the sub- oil. The extent to which the chemical prop- rties of soils change is closely associated with e soil texture, the thickness of the humus hor- on and its humus content, and also very often with the degree of podzolization. In slightly cultivated soils of low fertility having a humus horizon less than 20 cm thick, a coarse texture and a high or at least average degree of podzolization, the change of physicochemical properties resulting from liming is much greater than in cultivated soils which have a narrow humus horizon and finer texture and which are less podzolized.

A study was also made, in the same experimental area, of the effect of liming upon the content of mobile aluminium and of available phosphoric acid and nitrates; and also upon the soil's physical properties, its water- and air-permeability and bulk-density (3). A balance in mobile aluminium content was usually found in the second, and sometimes even the first year after liming. A half, and in some cases even a quarter amount of lime is enough for the mobile aluminium content to decrease in the first, or at any rate the second year after liming, to 0.2 or even 0.1 mg per 100 g of soil.

The effect of liming upon the content of available phosphoric acid was minimal; nevertheless there is as a rule more of it in limed than nonlimed plots. This difference increases as the amount of lime is increased.

Liming has a more positive effect on the nitrate contents in the soil: four years after liming the nitrate contents increases and runs parallel with the increase in the amounts of lime at all stages of the growing season.

The physical properties, primarily the soil's water- and air-permeability, also show certain changes after liming. The water-permeability of the finer-textured soil increased under the influence of liming, whereas that of coarse-textured soils declined. In both cases this had a positive effect on the soil's water regime. Air-permeability changes in the same way.

Table 3 illustrates the results achieved with liming in the nine experimental areas over a period of six to nine years. For standardization of yield, increases are shown in centner feed-units (c. f. u.). After harvesting, in the case of grain crops, only the grain was weighed; in the case of forage plants with edible roots, only the roots were weighed. In calculating centner feed-units the straw to grain ratio adopted was as follows: rye — 2.4; wheat — 2.0; oats — 1.5; and barley — 1.3. For forage root plants a ratio of leaves to roots of 0.3 was adopted. In calculating yields in centner-feed-units Muug's tables were used (7). In order to calculate total yields in centner-feed-units weights in centners are multiplied as follows: the weight of rye grain is multiplied by 1.71; wheat by 1.59; oats by 1.43; barley by 1.53; hay by 0.45; patio tubers by 0.30; beet-roots b 0.12; turnips by 0.14; and corn green leaves by 0.11.

Yield increases as a result of liming fluctu appreciably, and in some cases liming even re duced the yields. For example, this happened with rye at the Mooste and Symerpalu state farms, where ground rock phosphate was applied to fallow area in large amounts and its availability was reduced by the liming.

In some cases liming also reduced potato yields in fields where travertine was applied a a lime. When slate ash was applied, however potato yields always increased, as I. S. Veshe skaya also points out (1). A half amount of travertine in five experiments increased tuber yields by an average of 0.5 centner-feed-units per hectare; slate ash application in three experiments increased yields by 8.1 c. f. u. per ha (5).

Of the field crops the ones to react best of all to liming were the forage root plants. In three recorded years their yield increase aver aged 10.6 c. f. u. per hectare. Average yield increases of other crops were: barley for 8 years — 7.3 c. f. u.; forage grasses — for 21 years 3.8; oats for 10 years — 2.3; rye for 13 years 1.2; and wheat for 3 years average – 1.1 c. f. u.

The average yield increase obtained over a

Table 3

Yields obtained in period of experiments, c. f. u. per hectare

Place of experiment	No. of years	Average yield per year			Average incr. for year	
		Without lime	Limed		Half amount	Full amount
			Half amount	Full amount		
Mooste state farm	7	41.0	46.4	47.7	5.4	6.7
V. I. Lenin collective farm, Vyruskiy district	8	15.1	20.0	20.4	4.9	5.3
Julenurme state farm	8	53.2	58.6	56.2	5.4	3.0
Te kommunizmile collective farm, Tartu district, brigade III	9	12.3	15.3	16.3	3.0	4.0
As above, brigade II	8	20.1	23.0	23.8	2.9	3.7
Luuny'a state farm	6	26.6	29.2	28.9	2.6	2.3
21st June collective farm, Tartu dist.	7	21.7	24.2	25.4	2.5	3.7
Uus Elu collective farm, Tartu dist.	7	22.9	25.3	25.4	2.4	2.5
Symerpalu state farm	9	31.0	33.1	33.6	2.1	2.6

he recorded years in the different experimentl areas from one hectare after application of alf amount of lime fluctuated between 2.1 (Symerplau state farm) and 5.4 c. f. u. (Mooste and Julenurme state farms). In the majority the verage yield increase per hectare fluctuated etween 2.4 and 3.0 c. f. u. In all, with a total f 69 recorded years, the average yield increase of all the experimental areas comprised 3.5 c. f. u. per hectare.

The general background productivity level f the experimental area did not affect the size f the yield increase. Thus, in the Julenurme nd Mooste state farms, where the general ackground productivity level is extremely igh, an average increased yield of 5 c. f. u. vas obtained per hectare (in the former the nnual average yield was 53.2 and in the latter 41.0 c. f. u. per hectare). The yield increase n the V. I. Lenin collective farm reached almost the same level (Table 3). In the collecive farm the average obtained from the nonimed area was 15.1 c. f. u. per hectare.

As has been noted above, the amounts of ime applied in the experiments vary between ne eighth and double of hydrolytic acidity. One fourth and even eighth amounts — at least n the first years after liming — give considerble additional yields. But fairly soon they egin to decrease and the yields from the limed lots approach those of the control areas (4). The optimum amount must be considered to e the half, as has also been shown by experiments conducted by other research establishments, particularly the VIUA (2, 6). It is true hat if the amounts of lime are further increased the additional yields also increase — ut not in proportion to the quantity of lime aplied. Whereas a half amount gives an annual verage increase of 3.47 c. f. u. per hectare, he full amount increases the additional yield o 3.76 c. f. u. Thus one ton of lime is 1.8 imes more efficient if applied in half amounts han it is if applied in full amounts. The optinum amount of lime should be regarded as 5-7 tons per hectare. These are the amounts t present applied in Estonia. The liming of ne hectare of land, at an average of 6 tons er hectare, together with delivery and applicaion, costs 130 roubles (or 10 roubles where ayment is by the labor-day system). As a reult of liming, additional yields equivalent to 31.2 c. f. u. were obtained from one hectare ver a period of 9 years. Hence, the cost of ne c. f. u. in additional yields is 4.17 roubles, . e., the cost of one c. f. u. works out at only .2 kopecks. Nor must one ignore the fact hat in 1959 and 1960 the cost of one half of ime deliveries will be borne by the State, vhich also, if desired, make long term loans vailable to cover expenditure on the other half. Owing to these emoluments the economic effect f liming in collective and state farms will increase still further.

Thus the liming of acidic soils is one of the most important and at the same time cheapest measures for increasing gross agricultural output from the vast areas of the Soviet Union's sod-podzolic soils, as provided for in the seven years plan period which has now begun.

Conclusions

1. The average differences in chemical indices (hydrolytic acidity, content of exchangeable bases and degree of saturation) between non-limed soils and soils limed with quarter, half and full amounts (according to hydrolytic acidity) even in the eighth year remained practically at the same level as in the first year after liming. Where double amounts were applied, however, the differences considerably declined in the same period as compared with those obtaining in the first year after liming.

2. Changes in the average chemical indices for the plowed layer (0-20 cm) of limed (as compared with nonlimed) plots, in the eighth year after liming and depending upon the amounts, are as follows: content of exchangeable bases increases by 1.3-4.7 meq; degree of saturation increases by 12%-33%; hydrolytic acidity decreases by 0.4-1.6 meq per 100 g of soil. Differences in the chemical indices for the sub-soil (20-40 cm) are marked when single and double amounts of lime are applied.

3. The average increased yield as a result of half-amount of liming in nine experimental areas over a period of 69 recorded years was 3.5 c. f. u. per hectare per year. The highest average additional yields were given by forage root-plants, barley and perennial grasses.

4. With half-amounts of liming one ton of lime is 1.8 times more efficient than a full amount of liming.

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HE ''HEILUTU'' SOILS OF THE LOESS PROVINCE N THE HWANGHO RIVER BASIN[1]

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Ever since F. Richthofen's day and the early ublications of V. A. Obruchev, the soils of the ain part of the Loess province (Loess plateau) the basin of the Hwangho River have been alled "loessial" and an aeolian origin has been ttributed to them.

The American soil scientist Thorp (15) was e first to class them as "incompletely de- eloped light and very light chestnut soils." He dopted these terms temporarily, "for want of etter," intending to "put over the idea that ese soils seem closely associated with norm- l light and very light chestnut soils," but were t younger stages of development "because of lane erosion and silt deposits."

In Thorp's view the main signs of incomplete evelopment were a lighter coloring than in cor- esponding "normal" light chestnut soils and e absence of a "clearly marked accumulation f lime in the profile," with high carbonate ontent up to the surface. Exceptions were stances where there were layers of buried, arker-colored soils which, having previously ain closer to the surface, had been leached om carbonates and had "undoubtedly belonged the group of chestnut soils." The light and arbonate part of the profile formed above them horp associated with deposits of wind-blown ilt, pointing out its marked porosity, the pres- nce of carbonate mycelium and the 1.27% hu- ius content. As regards the buried soil he emarked upon its finer texture and the ab- ence of clearly defined carbonate horizons, hich were sometimes represented by small ccumulations of lime.

Thorp's views on the classification of the oils of the main part of the Loess province were widely accepted by Chinese soil scientists. Developing his theses, the latter distinguished different series of chestnut soils (Hsifeng, Changwu, Pigliang and others) and in soil maps and studies referred to the territory as being a zone of chestnut soils (8, 5, 13).

Such was the position until 1955, when joint excursions in the CNR by Soviet (I. P. Gerasimov, V. A. Kovda) and Chinese scientists (Ma Yung-chi, Sun Ta-cheng, Hsiung Yi, Huo Kwan-chiung, Weng Chang-wang, Chu Hsiang-mo and others) made it clear that it was wrong to distinguish a chestnut soils zone in the Loess province and that a new classificational treatment was necessary. On Gerasimov's suggestion the soils were defined as belonging to the group of grey cinnamon-brown soils on the basis, mainly, of a study of two profiles on the plateau of Hsifeng and in the area of the town of Wuchung (west of Hsian). The designation "grey cinnamon-brown" (attributed to I. P. Gerasimov) appeared for the first time in a report by Ma Yung-chi at the 6th International Soil Congress (14) and was used again in subsequent soil studies and maps published as a result of the joint work of Soviet and Chinese specialists (4, 2, 3).

Nevertheless the Chinese soil scientist did have certain doubts about grey-cinnamon-brown soils being so very widespread in the Loess province. Thus, in May 1957 in reports delivered by Ma Yung-chi and Chu Hsiang-mo at a conference in Peking devoted to program problems of the Central Hwangho expedition, references to the soils of the territory included certain other soils, known by the local name of "Heilutu" ("dark soil" in Russian).

That the Chinese scientists' doubts were well founded was confirmed by two years of field research (1957-1958) by the soil group of the Chinese-Soviet detachment of the Central Hwangho expedition. It emerged that the grey cinnamon-brown soils have a rather organic distribution and are mainly to be found only in the warmest and comparatively humid southern and southeastern parts of the Loess province. Characteristic of the main part of the province is the development of rather different soils, namely the heilutu.

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[1] From material supplied by the soil group of the mbined Chinese-Soviet detachment of the Central angho complex-erosion control expedition of the ademy of Sciences of the Chinese National Republic. ad of expedition: Ma Yung-chi; Head of soil de- hment; Chu Hsiang-mo; Scientific leader: A. N. zanov.

Studying the heilutu presents considerable difficulties, which is mainly why comparatively little attention has been paid to them. Exceptionally intense agricultural utilization of the Loess province coupled with extremely far-advanced erosion processes have led to an almost complete absence of natural soil profiles. They are to be found only in a few places, and then are largely buried — as Thorp noted. In the majority of cases, because of the erosion, only relicts of natural soils still exist; and these also are buried beneath new stratifications ("shutu" in Chinese) formed as a result of prolonged agricultural utilization — not, as Thorp supposed, from "wind-blown silt." In some places, however, erosion consequence, i. e, alluvium, have had something to do with this burying phenomenon.

Therefore in order to establish the character of the natural soils (which in the Loess province are now in fact buried) attention must mainly be concentrated upon the second part of the profile of the present-day soils, delimiting the upper stratified or covering part as being of a different origin and having properties that were examined in a previous article (10). We may observe that Thorp too referred to this delimitation. With such an approach forced upon us, it is naturally somewhat difficult for us to judge the true character of even the upper horizons of the former natural soils. First because they too have in the past been subjected to strong cultivation influences (such horizons are designated in the table by the symbol A^{-cult}); and second, these soils are at the present time being affected by the influence of the upper stratified part. It will also be realized that we have no means of reaching well-founded conclusions concerning the character of the natural vegetation of the past.

The description of heilutus given below is based on data from a fairly large number of more or less full profiles. It proved possible to secure several of the heilutu profiles from virgin sites or sites nearly untouched by cultivation (Profiles C-3, 32 and 67 in the table), which makes the task easier. The rest of the profiles are of old plowed heilutu soils and covered with a cultivated top layer, the peculiarities of which were studied in our article (10), and which enabled Thorp to refer to the "incomplete development" of the layer. For convenience the upper cultivated layer is not included in the study.

Table 1 includes a full profile Profile Y-5 in order to give a general idea of the old-plowed heilutus.

The development of heilutu is in a broad belt where absolute altitudes range between 80 and 1,800 m. In the southwest of the territory in connection with the increased dryness, thes soils are encountered at 2,000-2,400 m. Here special dark heilutus develop which can be regarded as a manifestation of vertical zonalit A variety of cinnamon-brown forest, brown forest and even mountain-meadow soils form in other areas at the same altitude, and in places a good deal lower.

The heilutus' predominant parent material are brownish-yellow loesses, but quite extensive areas of heilutu occur on sands and sandy loams, and instances of their forming on eluvium and deluvium of compact parent ma terials have been noted.

Heilutus develop under automorphous regin conditions, i. e., they have no connection with the soil waters, which lie at a very great dept below the surface. But heilutus of a hydromorphous subgroup have been observed in pla together with clear signs of water-logging in the soil profile. These soils are distinguishe by the name "meadow heilutus."

Inadequacy of data does not permit us at present to give a detailed description of the bioclimatic conditions in which heilutu soils have formed, and this applied even more so t the remote period before their cultivation began. Climatic conditions today, however, ar very generally as follows. The average annual precipitation fluctuates between 386 mm (Yuiling) and 520 mm (Hsifeng). About 60%-70% of it falls in July, August and September. Winter and Spring are the driest seasons of the year. The average annual air temperature i 8.5-10.5°C. The maximum is 39-39.6°C, minimum 24-27°. The winters are relatively cold with little snow and fairly deep frosts (up to 50-7 cm). In places the soil does not thaw complete until the end of May. The relative air humidi in the summer reaches 80% (Hsifeng). The free frost period fluctuates between 130 (Yuili and 160 days (Suiteh and Hsifeng).

Remnants of the natural vegetation indicate that it was steepe-like in character, at least in the northern part of the territory, where the species encountered belong to the grass-wormwood groups. Among the grasse several species of feather-grass (Stipa bunge S. grandis), couch-grass (Agropyrum cristat Aneurolopidienn dasystachis and others are found; and of the wormwood — Artemisia mon lica, A. giraldi and A. frigida. Shrubs are mainly Caragana stenophylla and Licium chinensis. As well as some typical examples of the steppe flora of a temperate belt there is the characteristic presence of bear-grass (Andropogon tchaemum), a typical indicator o plant communities of the subtropical steppes.

Table 1

Results of analyses of heilutus

Genetic horizons	Depth, cm	Humus %	C:N	Nitrogen			CO₂ %	% of particle diameters, mm		Exchangeable cations					Bulk density	Certain peculiarities of soil profile structure
				Total %	Slightly hydrolyzed					Total meq per 100g	% of total					
					mg/kg	% of total		< 0.01	< 0.001		Ca	Mg	K	Na		
Profile C-3. Light-colored coarse-clay loam heilutu (Suiteh) absolute height 1,400 m																
A′	0—10	0.72	8.4	0.054	31.1	5.7	0.46	23.8	11.2	12.5	88.8	11.2	None		1.25	Consistence rather friable, carbonate, mycelium
»	10—20	0.69		0.048	22.4	4.5	0.33	Not det'd.		Not det'd.			"		—	(same)
A″	40—50	0.69		Not det'd.			0.22	21.5	11.0	13.3	84.2	15.8	"		1.30	Rather friable, with holes, more mycelium
B_1	65—75	0.58		"			0.13	Not det'd.		Not det'd.			"		1.29	same
B_2	100—110	0.54		"			0.59	20.4	10.0	11.8	73.7	26.3	"		1.28	Same, but less mycelium
B_3	130—140	0.33		"			2.75	Not det'd.		Not det'd.			"		1.32	Still less mycelium
B/C	155—165	0.23		"			3.85	19.6	9.6	"			"		—	No mycelium; occasional veins of $CaCO_3$
»	180—190	Not det'd.		"			3.30	Not det'd.		"			"		1.27	No mycelium
C	235—245	0.10		"			4.62	13.8	6.5	"			"		1.29	same
Profile 104. Ordinary Coarse-clay loam heilutu (Lechwan), absolute height 1,045 m																
A′ cult	18—28	0.61		Not det'd.			1.32	26.7	10.0	11.5	91.3	8.7	Traces		1.35	Slightly compacted, sparse mycel.
A″	45—55	0.72		"			1.32	38.2	14.5	14.0	96.4	3.6	"		1.30	Rather friable, mycelium-pierced
B_1	80—90	0.50		"			4.95	37.3	15.1	13.0	92.3	7.7	"		1.26	Friable, large amounts of mycel.
B_2	110—120	0.35		"			6.71	36.1	13.9	10.0	95.0	5.0	"		1.21	same
B_3	140—150	0.34		"			5.50	33.8	14.2	Not det'd.			"		1.20	Mycelium in places, and very occasional specks of $CaCO_3$
B/C	160—170	0.26		"			6.16	30.4	11.3	"	"		"		1.31	Occasional veins of $CaCO_3$
C	193—203	0.30		"			6.05	31.4	12.8	9.5	84.2	15.8	Not det'd.		1.38	same
Profile 21. Ordinary medium-clay loam heilutu (Hsifeng), absolute height 1,400 m																
A′ cult	30—40	1.01	7.8	0.076	64.4	8.4	2.75	42.4	15.7	13.0	89.2	8.5	2.5	None	—	Slightly compacted, blocky, mycel.
A″	60—70	0.93		Not det'd.			3.74	43.4	15.8	12.6	96.8	3.2	None	"	1.19	Friable, much carbonate mycelium
B_1	85—95	0.71		"			6.05	42.9	15.1	11.1	99.1	0.9	"	"	1.14	Friable, mycelium-pierced thruout

Table 1 Continued

Genetic horizons	Depth, cm	Humus %	C:N	Nitrogen Total %	Nitrogen Slightly hydrolyzed mg/kg	Nitrogen Slightly hydrolyzed % of total	CO_2 %	% of particle diameters, mm <0.01	% of particle diameters, mm <0.001	Exchangeable cations Total meq per 100g	Exchangeable cations % of total Ca	Mg	K	Na	Bulk density	Certain peculiarities of soil profile structure
B_2	115—125	0.53		Not det'd.			6.60	40.0	14.0	9.9	90.9	9.1	None	None	1.28	Rather friable, less mycelium, krotovina
B_3	140—150	0.33		"			6.16	38.6	13.2	10.5	80.0	20.0	"	"	1.22	Same, but still less mycelium, krotovina
C	170—180	0.15		"			6.05	35.0	11.9	9.3	82.8	10.7	6.5	"	1.23	Somewhat compacted, occasional veins of $CaCO_3$
"	210—220	Not det'd.		"			6.05	33.1	10.7	Not det'd.					—	same
"	250—260			"			5.94	29.0	8.9	"					1.27	same
Profile U-5, Old-plowed heilutu, normal deeply cultivated, medium-clay loam (Changwu), absolute height 1,250 m																
A_n^{anth}	0—10	1.29		Not det'd.			4.18	34.7	13.0	9.8	81.3	15.3	3.4	None	—	Brownish yellow-grey with cinnamon-brown tint, without mycelium, worm-holes, potsherds and coal fragments
$A_{p\text{-}p}^{anth}$	15—25	0.88		"			3.41	37.5	14.9	9.5	84.2	15.8	None	"	1.53	
B^{anth}	30—40	0.58		"			1.70	Not det'd.								Lighter, mycelium, much of same sort of inclusions
$A^{\prime cult}$	52—62	0.75		"			0.66	41.9	16.7	16.0	81.2	18.7	None	None	1.46	Somewhat compacted, mycelium and some inclusions
A'	70—80	0.97		"			0.22	45.3	19.1	16.0	87.5	12.5	"	"	1.30	Rather friable, abundant mycelium, non-stable nutty structure many worm-holes
"	85—95	1.04		"			0.22	46.3	17.3	16.0	87.5	12.5	"	"		
A''	103—113	0.98		"			2.75	44.3	17.4	13.5	88.9	11.1	"	"	1.35	Same, but pierced throughout with carbonate-mycelium
"	115—125	0.94		"			4.73	Not det'd.		12.5	92.0	8.0	"	"		
B_1	130—140	0.72		"			5.66	43.2	16.9	12.0	91.7	8.3	"	"	1.26	Much mycelium, rather friable, deeply riddled
"	145—155	0.58		"			6.60	42.0	16.1	10.0	90.0	10.0	"	"		
B_2	17585	0.48		"			6.49	40.8	16.8	11.0	90.9	9.1	"	"	1.27	Less mycelium, less riddled
"	205—215	0.44		"			6.39	37.9	13.9	Not det'd.				"		
B_3	229—239	0.34		"			Not det'd.	35.4	14.0	"				"	1.39	same
"	260—270	0.26		"			6.61	34.7	13.5	9.5	84.2	51.8	None			Noticeably more compact, $CaCO_3$ veins, small isolated lime concretions

Table 1 Continued

Genetic horizons	Depth, cm	Humus %	C:N	Nitrogen			CO$_2$ %	% of particle diameters, mm		Exchangeable cations					Bulk density	Certain peculiarities of soil profile structure
				Total %	Slightly hydrolyzed					Total meq per 100g	% of total					
					mg/kg	% of total		<0.01	<0.001		Ca	Mg	K	Na		
C	305—315	0.23		Not det'd.			6.27	36.4	14.6	9.5	89.5	10.5	None	None	1.40	The same in compactness, occasional CaCO$_3$ veins
Profile 32. Dark medium-clay loam (Hwachaling), absolute height about 2,350 m																
A′	5—15	3.98	9.5	0.254	114.8	4.5	3.3	45.3	13.5	Not det'd.					1.12	Semi-sod, with mycelium
A″	27—37	2.37	8.0	0.171	98.0	5.7		44.6	17.4	"					—	Rather friable, much mycelium
B$_1$	45—55	1.82	8.2	0.129	92.4	7.2	4.0	45.2	17.7	"					1.17	Same, but still more mycelium, riddled
B$_2$	70—80	1.19		Not det'd.				41.7	17.1	"					—	Rather friable, less mycelium
B$_3$	100—120	0.88		"			7.0	41.2	15.9	"					1.20	Rather friable, pockets of mycelium in form of film
"	140—150	0.54		"				36.0	14.9	"					1.35	More compact, humus blotches and stains, carbonate films and rusty-ochrous specks from parent material
B C	180—190			"			6.8	38.1	15.3	"						
"	200—210			"			3.1	36.4	14.3	"						
Profile 67. Sandy-loam heilutu (Changchiapan), absolute height 1,490 m																
A	5—15	0.74	9.6	0.045	Not det'd.		0.33	14.4	6.5	Not det'd.					—	Rather friable, sparse carbonate mycelium
B$_1$	30—40	0.62	9.1	0.039	"		0.44	13.2	5.8	"					—	Friable, carbonate mycelium
B$_2$	60—70	0.54		Not det'd.			0.11	9.6	4.8	"					—	Same, holes
B$_3$	90—100	0.26		"			1.65	8.5	4.5	"					—	Rather friable, with mycelium and specks of CaCO$_3$
B C	125—135	0.21		"			1.10	7.0	4.0	"					—	Sand with krotovina and occasional carbonate veins, effervesces with HCl from 83 cm
"	160—170			"			2.20	6.3	3.8	"						
C	190—200			"			2.53	5.2	3.1	"					—	Friable sand without carbonate precipitates

Notes: 1) Analytical methods: humus — Tyurin; nitrogen — Kjeldahl; slightly hydrolyzed nitrogen — Tyurin and Kononova; CO$_2$ — Golobev, particle size — Kachinskiy, with sodium hexametaphosphate treatment of soil; exchangeable Ca and Mg — Shmuk; K and Na — Gedroyts, with Ivanov's spectroscopic method. 2) Analyses in laboratory of genesis and melioration of salinized soils of V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR were performed by: N. Ivanova, A. Kozlova, V. Molodtsov, G. Shelonina.

Less xerophytes are found in the central, eastern and southern parts of the territory, where there are less wormwoods, and more grasses of various species, with bear-grass occurring much more frequently. Of the shrubs there is a marked preponderance of ziziphus (Ziziphus jujuba, v. Spinosa) and other examples of southern flora.

The Chinese geobotanists go into the greatest detail in distinguishing geobotanic districts and zones in this territory. Tsui Yu-weng (16), for example, distinguishes several botanical-geographical districts which he combines into two zones — a steppe zone and a forest-meadow-steppe zone. The boundary between them lies along the west and northwest slopes of the Liuliangshan range, and then intersects the middle reaches of the Loho and Chingho Rivers. In the steppe zone he distinguishes a northern part (the driest and less warm), a central and a southwestern part. The forest-meadow-steppe zone is divided into three districts.

All the heilutus of the automorphous series have the same sort of soil profile structure, regardless of their different situations and parent materials.

If we generalize the descriptions of soil profiles of clay loam heilutus we have the following:

A' thickness (conditional), 15-30 cm. Cinnamon-brown light grey color at field moisture (according to A. C. Bondartsev's color scale): coffee, tobacco-brown, or light chocolate coloring; in dry state: light cinnamon-brown, brownish or dark sandy color; structure loose powdery fox blocky; contains carbonate mycelium or carbonate film.

A'' thickness, 30-45 cm. Rather lighter, but of the same coloring tone; friable composition with abundant carbonate mycelium; without structure or non-stable nutty to blocky, riddled with passages made by burrowing creatures, mainly earthworms, and root channels.

B_1 thickness, 20-35 cm. Greyish cinnamon-brown, remainder as preceding.

B_2 thickness, 15-30 cm. Lighter and less homogeneous in color, with a trace of parent materila; without structure, rather friable consistence; also riddled with passages; occasional krotovinas; less carbonate mycelium.

B_3 thickness, 20-50 cm. Still less homogenous coloring due to greyish cinnamon-brown blotches and stains standing out on brownish-yellow background derived from parent material; without structure, less friable, less riddled with passages; occasional krotovinas; carbonate mycelium in pockets and less pronounced, a few carbonate concretions. Transition to parent material gradual and boundary with horizon C not clear: B/C transition horizon sometimes marked by scattered and indeterminate greyish cinnamon-brown blotches and separate carbonate views. Parent material: loess of a brownish-yellow color, not containing salt, gypsifer and carbonate precipitation. Very occasional specks and veins of $CaCO_3$.

This profile description relates mainly to t ordinary or typical heilutu soil. It differs a little from descriptions of the light heilutus found in the northern parts of the Loess province and the dark heilutus of high altitudes. Generally speaking, the same applies to the coarse-textured heilutus, but they are not usually found to effervesce in HCl. Despite this, carbonate mycelium is nevertheless present, although in much smaller quantities.

In ordinary heilutus the total thickness of horizon A varies between 50 and 70 cm; of horizon A + B, 75-95, and of the whole profil (A + B), 150-165 cm. These figures show that the heilutus are soils with a thickly developed humus layer. In thickness of A + B_1, horizons they compare with the thick and superthick chernozems of the Ukraine; and in thickness of the whole profile they compare with the chernozems near the Caucasus and th Azov Sea.

The actual quantity of humus in heilutus is small. Humus content in horizon A' is as follows: 0.7%-0.8% in light-colored heilutus; 1.0%-1.2% in ordinary heilutus; and 3.5%-4.0% in dark-colored heilutus. However in sandy loam heilutus, which in most cases are still in their natural condition, the humus content is not less than in light-colored and ordinary heilutus of clay loams (Table 1). The explanation of this anomaly is that the latter have los a large portion of humus due to long periods under the plow. According to data furnished by Gavrilynk (1), even the Caucasus chernozems have lost about one-third (32%-38%) of their humus in 50 years' cultivation; the humu content of old-plowed soils of this type is now 2.6%-2.7%. Thus the humus content quantitie given for ordinary and light-colored heilutus should be at least doubled in estimating its quantity in the former natural heilutus. Even with this correction, however, the humus content is very small. In this respect the heilutus belong to the same subgroup as the sierozems of Central Asia.

The carbon/nitrogen ratio in heilutus is fairly narrow, fluctuating between 7 and 9.5. It is somewhat broader than in Central Asian sierozems, but is narrower than in the chestnuts and chernozems of the USSR. One may therefore talk of a somewhat different quality of humus composition.

This supposition is confirmed by research arried out at our request by V. V. Ponomareva. ere conclusion was that the composition of the umus in the sample of dark heilutu studied Profile 32) was "unique, and bears no great esemblance to that of any of our soils..." particular, the heilutu contained far less of e humin acids fraction than chernozems far ore fulvic acids which dissolved upon ignition. onamareva associates this sort of humus con-nt with peculiarities of climate, which (on the asis of the character of the humus substances) ne describes as "not continental and not cold, ore likely southern, but not subtropical."

The total nitrogen content is small (0.05%-2%), and the quantity of readily hydrolized trogen relatively great. In light-colored eilutus it amounts to 20-30 mg/kg; in ordin-ry heilutus 50-70; and in dark heilutus it in-reases to 90-115 mg/kg. Hence, except for e light-colored heilutus, these soils contain eadily available forms of nitrogen in sufficient uantities to satisfy crop requirements for this ement. The content of readily hydrolized ni-rogen varies between 4.5% and 8.5% of the total trogen content, i. e., it is higher than in the hernozems of the USSR, but lower than in the erozems of Central Asia, approximating more the northern cinnamon-brown soils of Eastern ranscaucasia (12).

A characteristic feature of the heilutus is eir carbonate profile. The great majority e carbonate up to the surface. But one does ncounter slightly-leached heilutus with a bare- perceptible CO_2 content in horizon A (Profiles -3, U-5, Table 1). As a rule the upper heilutu rizons, covered with a cultivated layer and nanged in the past by agricultural utilization orizon A'cult. or A''cult.), have an increased ntent of carbonates, which must be a result their illuviation from the upper, covered yer. This basic illuvial-carbonate horizon, corporated in horizon B, is fairly clearly arked compared with horizon A. As regards uantities of CO_2 there is, however, compara-vely little to distinguish it from the parent aterial. In the sands and sandy loams heilutus rbonates are not usually present in the upper rizons, and make their appearance only in e lower part of the soil profile.

A typical form of carbonate precipitation, seudomycelium, is to be found even in the ndy loam heilutus. However their CO_2 con-nt is so small that it cannot be detected anal-ically (volumetric determination of CO_2). ccording to N. G. Minashina's micromorphologi-l investigations, the carbonates in the upper d middle part of the heilutu profile (Profile 21) onsist only of secondary calcite, in the form aciculate crystals which are known by the me of lublinite. Accumulations of these ystals thickly cover the surface of the soil icroaggregates and the walls of the various pores, giving the impression of carbonate mould or mycelium. Such crystals are not found inside the microaggregates however. This explains the absence or small content of CO_2 in some heilutus where there is a carbonate mould, the mass of which is insignificant in relation to the total volume of the soil layer. In the remaining part of the profile, on the other hand, beginning with horizon B_2, one encounters primary (calcite and dolomite) and secondary carbonates, the latter consisting of fine-grained calcite crystals distributed evenly on a thin-section or on microaggregates.

The friable consistence of heilutu noted previously has been confirmed by determining bulk densities. As a general rule the bulk-density of heilutu is not more than that of the loess parent material. Often it is even less. It is least in the middle part of the profile, that is in the most friable and riddled and, hence, the most porous part. According to Minashima's micromorphological investigation, the middle part of an ordinary heilutu profile (Profile 21) is three times as porous as the loess (horizon C). As the data indicate, the heilutus have nothing resembling compacted horizons, a circumstance which is duly reflected in the soils' morphology.

Particle size analyses of the heilutus have shown that in the course of their formation finely dispersed particles (of fine silt and clay) increase (as compared with the parent material) in the upper part of the profile and larger fractions correspondingly decrease. This redistribution of particle sizes enables one to speak of a "clay formation" process taking place in the heilutu soil mass. But this process is not peculiar to any particular genetic horizons; it affects all that part of the profile where the humus content is most marked. Another peculiarity is that the quantity of finely dispersed particles forming is comparatively small (12%-16% of the particle diameters <0.001 mm in coarse and medium clay loam heilutus). It is therefore only in rare cases that the clay formation involves any changed nomenclature as regards the texture of the soils and parent materials. Thus, by content of physical clay, the heilutus of Profiles C-3, 21, 104, and 32 belong to the same category of coarse and medium clay loams as their corresponding parent materials (Table 1).

The field descriptions do not show any noticeable addititional fine texture in the soil profile. Hence, the clay formation in heilutus is of the "hidden" type, as it is in the sierozems of Central Asia. As regards the quantity of clay particles formed, however, the heilutus occupy an intermediate position between sierozems and grey — cinnamon-brown soils, including those which are to be found in the Loess province.

The exchange capacity (total adsorbed cations) in heilutus is 10-16 meq, i. e, rather higher than in sierozems, but less than in the chestnut soils of the USSR. In the parent material, however, it is not more than 9.5 meq. It is clear from this comparison that the process of heilutu soil formation is accompanied by an accumulation of exchangeable bases.

The composition of exchangeable bases in heilutus (in horizons A, B_1 and partially B_2) is 85%-96% calcium, with occasional divergences above and below. The balance is magnesium. Exchangeable potassium and sodium are totally lacking, or occur in the form of traces. Only now and then are the soils found to contain small quantities of exchangeable potassium in horizon A' – the result, apparently, of cultivation and biological accumulation.

The lower part of the heilutu profile, beginning with horizon B_2 (partially) and B_3, and the underlying strata of parent materials contain larger quantities of exchangeable magnesium (up to 16%-26% of the total). Exchangeable potassium and sodium was not found here either, except in one case (the layer at 170-180 cm in Profile 21).

This composition of exchangeable bases shows the heilutus to be soils that are completely not solonetzic. The well-marked predominance of exchangeable calcium and their carbonate content endow them with a stable weak-alkaline reaction. It can be assumed that the heilutus have not passed through a salinization stage during their formation, for if they had then there would be noticeable quantities of exchangeable alkaline cations and larger amounts of exchangeable magnesium present in the soil profile. If there was such a stage then it was apparently of short duration, a substitute stage of deep-going desalinization and leaching.

The thesis that the heilutus are not salinized soils is confirmed by the absence of soluble salts and gypsum in their profile. Our field investigations showed no gypsum precipitations up to two to three meters and deeper, and qualitative reactions to Cl^- and $SO_4^=$ were always negative. The absence of primary (fragmented) carbonates in the upper and middle parts of the heilutu profile, or their presence in small quantities (as was frequently observed), is explained by intense leaching.

The heilutus have no agronomically valuable macrostructure. The powdery (powder-like), small blocky and sometimes nutty structural units found in the upper horizons are not stable. On the other hand micromorphological investigation shows that the heilutus have a well-defined, stable microstructure (Profile 21). This property together with their friable consistence, create the conditions for deep infiltration of atmospheric precipitations, help to conserve the soil moisture and help the crops to make the right use of it. Significant in this respect are the follo ing data concerning field moisture in an ordina heilutu (Profile 20, Hsifeng plateau). They re fer to a field of winter wheat stubble before th rainy period (June 6, 1957).

Depth, cm	Percent moisture
5– 15	15.4
32– 43	21.1
72– 83	22.1
156–163	19.0
210–213	16.1

Notes: 1. Field (min mum) moisture capaci according to data of Hsifeng experimental station, is 15%; this quantity clearly understated owing to inadequate measures agains evaporation. 2. Satur tion moisture capacity about 30%. 3. According to data from same station, moisture in la down to 70 cm in summ rainy period (July-Aug reaches 24.8%.

The figures given indicate, firstly, the large amounts of active moisture available by the time the fallow soil is put to the plow for the next winter wheat; and secondly they permit the assumption that the moisture regi of these soils, developed in plateau conditions with average annual atmospheric precipitatio of 520 mm, includes periodical leaching. We may point out that Rode (9) assigns certain groups of chernozem and chestnut soils to thi type of water regime. In the drier regions where heilutus are found ("light-colored" heil tus, to use the accepted terminology) the wat regime is apparently of the non-leaching type. However observations made in the area of Lishang in a hilly locality (the profile was a cut on a flat hill-top), and in the very dry yea of 1957, showed the moisture profile of a layer of coarse silty clay loam 8.5 m thick to be as follows. From the surface to approximately 1 m depth the moisture fluctuated between 8.5% and 10%; between 1 and 2 m it was 11%-12%; between 2.5 and 5 m it was 14%-16 between 5.5 and 7 m it was 15%-17%; and between 7.5 and 8.5 m it was 13.3%-13.8%. Thu only the upper layer, one meter deep, was cried out by the end of July to about the moisture-fading level. The layer between 2.5 and 7 m retained moisture at about the minimum moisture capacity level; and only at depths greater than 7.5 m was there a transition to the "dead" horizon, i. e., to strata which are stable in their moisture content.

These data are too incomplete to enable o to state an opinion as to the type of water regime in the soils under study. We have dwelt on them only in order to emphasize our view that special observations of the water regime of these soils should be undertaken.

The heilutu areas are a completely isolate ricultural zone with a very high degree of nd utilization, the basic cultivation being at of grain crops. With favorable weather nditions and good fertilization quite a high op yields are obtained from ordinary heilutus 20-25 centners per ha of winter wheat and gher. The light heilutus are less fertile. here is not much livestock because of lack natural forage and incorrect sowing of grass- . This is one of the main reasons for the ck of organic fertilizers which the heilutus gently need, particularly when subject to osion. Small areas are under irrigated riculture. These are to be found in river lleys and along the bottoms of ravines where plies of water for irrigation are available. hey are well cultivated lands producing good elds of different kinds of agricultural pro- cts.

As can be seen from the foregoing material, e heilutus, in their structure and properties, e a highly individual group of soil. It would difficult to find others like them among the own soil groups.

Least of all do they have in common with e light chestnut soils — the category in which horp placed them. They differ from the latter their non-solonetzic character, friable con- stence, structure of humus and carbonate ofile and other features. They also differ preciably from the non-salinized and non- lonetzic chestnut soils of Eastern Siberia, rst in their bioclimatic development condi- ons, and second in structure of the entire ofile. According to data furnished by Nogina) and Ufimtseva (11) these soils are character- ed by the small thickness of their humus hori- ons, leaching of carbonates from the upper rt of the profile, and the mealy nature of eir carbonate precipitations. The strucuture chestnut soils in the Mongolian People's Re- blic which also belong to the non-salinized and n-solonetzic group, is similar, but some of ese are "slightly compacted and fissured" , pp. 175, 158, 149) and even solonetzic (p. 4). Thus the chestnut soils of Eastern beria and the Mongolian People's Republic ck such morphological signs characteristic the heilutus as large thickness of the humus ofile, friable consistence and abundant pres- ce of carbonate pseudomycelium. Unfortun- ely data on the chestnut soils of Northeast ina are inadequate; this makes it difficult differentiate between them and the heilutus d impossible to contrast the two. Thorp wever was definite enough in this identifica- n of both in the soil map and in his monograph.

Nor would it be correct to describe the heilu- s as belonging to the sierozem soil group, though as shown previously, the two do have rtain things in common.

It is difficult to agree with Gerasinov's suggestion (2) that they be placed in the grey — cinnamon-brown group, for the heilutus do not show the morphologically developed clay formation in the soil profile that is characteristic of grey — cinnamon-brown soils. However, one of the profiles in the Wuchung area (Profile 15) described by him as also considered by our soil group, which studied this territory, to be a profile typical of the grey — cinnamon-brown soils of the southern parts of the Loess province.

The heilutus have certain general features in common with the chestnut soils and chernozems of the Caucasus, despite their tremendous distance from the Loess province. for example; thickly developed humus profiles, the mycelium character of carbonate precipitates, the hole-riddled nature of the soil, its high carbonate content. There are also great differences between the two. Thus, the Caucasus chestnut soils differ from the heilutus in horizon A'', in the fact that they are quite often solonetzic, in their incomplete stratification, and in their formation of calcium carbonate white flecks after the mycelium horizon (6). As for the chernozems of the Caucasus they can be distinguished by their high humus content, its different composition, their high exchange capacity, and lower-lying carbonate mycelium horizon.

All in all there is more data for classifying these soils as a special facial soil group of the sub-Boreal warm steppes (and forest steppes?) with a monsoon type climate and special development features. It is suggested that they be called by the old Chinese name "heilutu," like the way in which many other soils have been named. This proposal, put forward by the soil group of the Chinese-Soviet detachment of the Central Hwangho expedition, has been supported by the Chinese scientific community and has found a reflection in certain soil maps (4) and in the division of the CNR into districts according to their soil geography. Nevertheless the problem cannot be regarded as finally solved. Research on the heilutus must be continued; there must be more thorough-going comparisons between them and other soils which are related to them as regards development conditions and properties. Naturally it is still too early to form an opinion as to their genesis.

As for the present-day soils of the agricultural areas in this part of Loess province they are heilutus which have undergone great changes as a result of erosion and extremely long periods of cultivation. As explained previously we have dealt with these factors in another article (10).

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DISCUSSIONS

LASSIFICATION OF WATER-DEPOSITED SOILS[1]

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The classification of water-deposited soils important from both the theoretical and pro- iction points of view. A unified classification such soils is essential in compiling detailed il and soil-erosion maps. The productive po- ntial of water-deposited soils varies; more- rer, since they occur concurrently with soils at have been eroded, they give some idea of e intensity of erosion of adjacent territory ing at a higher level. The depositing of the il takes place as the streams slow down and come quiet which is caused — other things ing equal — by changes in the meso- and icrorelief (bottom ends of slopes, concave rts of combined slopes, furrows, tillage ruts), d also by vegetation and other artificial and tural obstacles. Most of the water-eroded aterial is carried away from the fields and posited in the form of deluvium on gully and vine bottoms and as alluvium in rivers, reams or other water-courses, silting up vers, ponds and reservoirs and making them allower. Much of the eroded soil is carried f by way of gullies, ravines and rivers to e seas and oceans.

Much less has been written about water-de- sited soils than water-eroded ones, although ie comes across references to them at the d of the last century.[2]

Dokuchayev (4) notes a "thickening of valley ernozem on the lower third of slopes." In lly places in Nizhegorod government (guber- ya) "the chernozem ... has in some places (where the land undulates more gently) become thin, in others (the tops of sharply contoured hills) it has completely eroded ..., and in others, along the lower-lying parts, this soil has become abnormally thick from the alluvium from higher levels." In the non-chernozem districts of Nizhegorod Government Dokuchayev also notes "influxes along the lower slopes" (water-deposited soils — G. P.) and soil erosions sometimes amounting to 10% of the total area.

N. M. Sibirtsev (11) also remarks upon water-deposited soils; he too calls them alluvial. "Water-eroded and deposited soils," he writes, "are widespread in the Starobel'skiy area, in addition to chernozem clay loams and chernozem sandy loams..." The same work points out that "clay soils deposited by water are accumulating in gullies" and that "the ravine beds are getting considerably wider and the bottom is filling up with clay chernozem alluvial soil."

F. Yu. Levinson-Lessing (8), examining the dependence of erosion upon relief, notes that the "concave nature of certain parts of the slope ... aids in depositing soil." Ya. N. Afanas'yev (1) points out that, during plowing, depressions get silted up with soil material carried down from neighboring plots. V. G. Kasatkin (5) says that the "most stratification of water-eroded and water-deposited podzolic soils" is to be observed on slopes, while in "depressions and sometimes even on level areas near hilly formations the horizon A_1 thickness increases to 50-70 cm." V. P. Yunitskiy (21) points out that horizon A_1 is the least thick on the steepest slopes: as the gradient gets more gentle it gets somewhat thicker, and in the hollow at the point where two slopes meet its thickness rises noticeably.

Water-deposited soils are also described by S. L. Shchekleyn (20). Designating them as soils which occur concurrently with water-eroded soils, he points to the formation of water-deposits as a result of eroded material being posited on the lower slopes. He observes that the combination of water-eroded and water-deposited soils is encountered almost continuously where the relief is undulating and hilly; and he evaluates water-deposited soils from the agricultural point of view. "Water-deposited soils, thickened as a result of surface accretions, with an upper layer of 30-50 cm and more, and distinguished by high fertility, form at the foot of slopes." Drawing attention to the high fertility of water-deposited soils, he remarks that "the depositing processes often bring about the silting of good soils, the transposition of planted seeds and sprouts, the silting of ridges and so on." Shchekleyn mentions lightly-deposited, deposited and also buried soils, but does not elaborate the principles underlying this subdivision.

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[1] Report at the first delegates' congress of soil ientists, to subsection on "Control of Soil Erosion." iy, 1958.

[2] This paper surveys the literature only of our own intry, since the proposed classification consists our view) of a further elaboration of the classi- ations of water-deposited soils already available the USSR. Most foreign classifications until re- itly have not taken the individual genetic soil hori- is into account, but have dealt with the whole upper er, i.e. the "top soil."

S. S. Sobolev (14, 15) gives a detailed description of a method for quantitative calculation of the intensity of the processes by which erosion products accumulate. He identifies the particular stratification and assortment features of these products with regard to texture and structure.

It was A. Kostyuchenko who made the first really systematic attempt to subdivide water-deposited soils into groups (6). This was in 1937. He divides them into three groups, according to thickness of the deposited layer: thinly-deposited, medium-deposited and thickly-deposited. He describes as thinly-deposited those soils in which the deposited layer comprises 10%-20% of the humus horizon situated under the deposited layer. Medium-deposited soils are those with a deposited layer which is 20%-40% of the initial humus horizon. Thickly deposited soils are those in which the thickness of the deposited layer is more than 40%. For each group Kostyuchenko shows the percentage decrease in humus.

Thus Kostyuchenko's classification is based on the thickness of the deposited layer as a percentage of the buried humus horizon. According to our observations (9), the content of humus in water-deposited soils is not, basically, associated with the degree of deposition, but with the soil group and depends upon the sort of material (horizon) from which the deposit derives. For example, when it derives from soils with a thick humus horizon the humus content in the deposited soils (irrespective of the deposition group to which they belong) may not diminish (the more so, in that a sorting activity is inherent in erosion). Moreover, the humus content in the upper part of the deposited layer may alter, irrespective of the alluvium degree, as a result of changing conditions (for example, the plowing up of tracts of virgin soil situated at a higher level or, on the contrary, their afforestation or transformation into meadowland).

N. N. Bolyshev (2) subdivided water-deposited soils (grey forest-steppe soils[3]) into separate groups taking into account the thickness of the plow layer and genetic horizons. He groups them under two headings: primary-deposited and secondary-deposited.

Bolyshev describes as primary-deposited soils those in which a water-deposited layer covers an upper horizon of non-eroded soil; and he gives the name secondary-deposited to water-deposited soils which have earlier unde gone water-erosion, the depositing process b ing a secondary process.

Bolyshev bases his further subdivision of b water-deposited and water-eroded soils on th thickness of the horizons $A + B_1$ and the maximum thickness of the plowed layer for the are concerned. He divides primary deposited and secondary-deposited soils into three groups according to the degree of deposition, as follows: thinly-deposited; medium-deposited; thickly-deposited. In the thinly-deposited group Bolyshev places soils in which the wate deposited layer does not exceed the thickness the plowed layer. In the medium-deposited group he places soils which have a "humus layer" (apparently he has the water-deposited layer in mind) 20 cm, but less than the sum c horizons $A + B_1$ in normal types. In the thickly-deposited group he places soils in which th water-deposited layer exceeds the thickness c horizons $A + B_1$ in normal types. This subdivision, as the author himself remarks, give an idea of the morphology and productive valu of the individual varieties of water-deposited soils, enables us to compare them and to collate them in groups according to their productivity.

Bolyshev corroborates his grouping of water-deposited soils with the morphological indices of these, and also water-eroded soils and with data obtained from texture and chemical analyses of primary-deposited soils. According to these data the water-deposited laye has the greatest quantity of clay particles and is characterized by a high content of nutrients in the plowed layer.

Bolyshev's work has the following positive aspects: 1) Subdivision of water-deposited soils into groups considering the thickness both of the plowed layer and of genetic horizons $(A + B_1)$; and 2) separation of these groups by the morphological signs of grey forest-steppe (grey forest) soils and partly by data of texture and chemical analyses of primary-deposited soils.

Bolyshev's conclusion that water-deposite soils contain more nutrients in the plowed la is not applicable to all water-deposited soils.

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[3] Grey forest soils.

he chemical and physical properties of the ater-deposited layer is very largely deter- ined by the character of the original soil ma- rial.

A. S. Skorodumov (12, 13) distinguishes four grees of water-deposited soils: thinly-de- osited, medium-deposited, thickly-deposited, d alluvia. In the thinly-deposited group he aces soils with a <25 cm thickness of the de- osited layer — with ordinary tillage some rt of the main soil may be taken up. In the edium-deposited group he places soils with 25-50 cm thickness of the deposited layer, hen in ordinary tillage only part of the water- posited layer is plowed up. In the thickly- posited group he places soils with a 50-100 n thickness of the deposited layer, when most all the roots of the agricultural plants ccur only in the water-deposited layer.

In the alluvia group he places water-deposited oils in which the deposited layer is more than 00 cm thick, and the buried soil consequently s only a small effect upon the agricultural ants.

Among water-deposited soils Skorodumov 2) also distinguishes soils which he describes eroded-deposited, i. e., soils which were rst subjected to water-erosion and which ter — in connection with changed conditions — derwent water-depositing. Eroded-deposited oils are subdivided into eroded thinly-de- osited, with a deposited layer of <25 cm; oded-deposited, with a 25-50 cm deposited yer; and eroded thickly-deposited, with a -100 cm deposited layer. Skorodumov notes at water-deposited and eroded-deposited soils ve a different productive potential to eroded oils.

Thus Skorodumov's classification takes into ccount both the depth and fertility of the plowed yer and the depth at which the basic mass of ricultural plant roots occur. Eroded-de- osited soils are analagous to the secondary- posited soils described by Bolyshev.

S. S. Sobolev (16, 17) recommends that water- posited soils be subdivided according to the ickness (multiple thickness of plowed layer) the water-deposited layer of erosion pro- cts and according to the composition of these oducts. In the event of the deposit taking the rm of fine earths resulting from the disturbed mus horizons the deposited soils are marked increased fertility. If the deposit on the sur- ce of the soil consists of materials from the eeper, less fertile horizons, or from the sub- oil, then the water-deposited soils are of low rtility.

I. A. Vlasyuk (3) notes that there is no gen- rally accepted classification of water-eroded d, particularly, water-deposited soils, and this lowers the quality of soil erosion maps; he also draws attention to the paucity of written material on the subject. He believes that there is no need for large numbers of different designations for water-deposited soils and that for practical purposes three groups are enough. He therefore divides them into three groups according to thickness of the deposited layer: thinly-deposited, in which the thickness of the deposited layer does not exceed the plowing depth of 20-30 cm; medium-deposited, where the deposited layer corresponds to the thickness of the root-bearing layer of 80-100 cm, and thickly-deposited, in which the deposited layer exceeds 100 cm.

A distinction in the case of soils deposited upon water-eroded soils — eroded-deposited and secondary-deposited — Vlasyuk regards as unnecessary, since these soils are limited distribution and can be classified for mapping purposes as water-deposited.

With this opinion one can only agree insofar as small scale mapping is concerned. In detailed research distinctions must be made in the case of water-deposited and secondary-deposited (or eroded-deposited) soils, since their fertility is different. Such distinctions are also essential for the elaboration of theoretical questions. M. A. Kochkin (7) subdivides water-deposited soils into three groups: thinly-deposited, with a 20-25 cm deposited layer; medium-deposited, thickness of deposited layer 25-50 cm; and thickly-deposited, thickness of deposited layer 50-100 cm and more.

It follows from this survey that at present there are six classifications of water-deposited soils. They differ both as regards the principle and signs on which they are based and as regards the number of gradations into which the soils are subidivided. Four of them subdivide water-deposited soils into three groups, and Skorodumov's classification distinguishes four groups. Subdivision is based on the thickness of the deposited layer: in centimeters (Skorodumov and Kochkin); as percent of thickness of humus horizon (Kostyuchenko); percent of thickness of the sum of horizons $A + B_1$ and maximum depth of the plowed layer (Bolyshev), and thickness of plowed and root-bearing layer (Vlasyuk).

Furthermore, Bolyshev and Skorodumov subdivide water-deposited soils with groups according to markedness or absence of signs of water-erosion in soils which have later been water-deposited; and Sobolev recommends that water-deposited soils be subdivided not only according to thickness of the deposited layer, but also according to the composition of the products of the depositing process.

In the Soils Erosion Laboratory of the

Dokuchayev Soil Institute a new classification of water-deposited soils is being worked out on the basis of their subdivision according to degree of deposition. In detailed soil-erosion research they are being subdivided into smaller groups — gradations of deposition. The classification takes into account the soil group and degree of deposition, if eroded soils are subjected to depositing, and also the composition of the water-deposited layer. In working out the classification it is in our view necessary to proceed from the following propositions.

1. The classification of water-deposited soils must have productivity and theoretical significance; it must reflect the natural fertility of the soil and further the study of theoretical questions not only of water-depositing but also, and to the same extent, of water-erosion, in as much as water-deposited soils, being concurrent with eroded soils, also partially reflect the water-erosion process.

2. The classification of water-deposited soils cannot be isolated from that of soil groups — it must supplement the latter; if water-eroded soils undergo depositing then the classification of eroded soils must also be taken into account.

3. Soil fertility is determined by the fertility of all the genetic horizons. These are continuously inter-related, but have different chemical and physical properties; and in this connection the plants' root system is also irregularly distributed in the soil (18-19).

4. Soil fertility is basically determined by the fertility of the plowed and, to a lesser extent, the subsoil for it is in these layers that the basic mass of agricultural plant roots is concentrated. Therefore the fertility of water-deposited soil will depend upon the fertility of the water-deposited layer and of the soil below it, and if the soil is water-eroded, upon the degree to which this is the case.

5. Water-deposited soils with analagous plowed layers will have different fertility depending upon the depth of the most fertile or least fertile horizon inherent in each particular soil group.

Hence, in classifying water-deposited soils the soil below the water-deposited layer must be determined first of all; this does not present any difficulty, for the water-deposit does not disturb the soil profile. The thickness of the water-deposited layer is then determined in relation to the thickness of the genetic horizon of the soil concerned. Here it is also essential to take into consideration whether it is non-eroded or eroded, and record the degree of erosion. It should be noted that soils are also encountered in nature in which the water-deposited layer, apart from its inherent stratification, is not homogeneous and has different pro erties and hence different fertility. For it ha occurred as a result of the depositing of products deriving from the destruction of the plowed layer not only of non-eroded, but also of eroded soils, and also originates in the ma terial of deeper horizons and even subsoil material carried up from places hollowed out by water. Such soils with a double, triple or multiple profile of the water-deposited layer are observed fairly often, particularly in the sod-podzolic zone, where the thickness the upper horizons of the soil is small, and th horizons sharply differentiated. The formatio of these soils is a result of the accumulation o water-erosion products from areas situated at higher levels, whose soils change as a result of erosion and are transformed from non-eroded into eroded soils with an ensuing change in degree of water-erosion.

Sometimes we encounter soils in which the water-deposited part has formed out of the plowed layers of water-eroded soils and is covered with material washed away from the plowed layers of non-eroded soil. This sort of change is usually associated with the cultiv tion of virgin soils and the slowing down of the water-erosion process in areas with eroded soils, where a water-erosion process has pre viously been taking place. Water-deposited soils with a non-uniform deposited layer we denote by the supplementary index letters "SM (water-deposited SM, i. e., water-depositing from the plowed layers of water-eroded soils) and by indicating the thickness and genetic origin of the separate parts of the deposited layer. For example, in medium-deposited SM, sod-medium-podzolic soil, in which the deposited layer represents a triple alluvium consisting at the top of 6 cm of soil material water-eroded from the plowed layer of a medi um-eroded soil (i. e., a soil in which the plow ing depth includes horizon B_1); below that — of 10 cm from the plowed layer of a slightly-eroded soil, in which the plowing depth includ horizon A_2; and below that again — of a 10 cm thick layer from the plowed layer of a non-eroded soil (i. e., a soil in which the plowed layer consists basically of horizon A_1), is denoted: medium-deposited SM, sod-medium podzolic soil: B_1 — 6; A_2 — 10; A_1 — 10. T letter designations can be replaced by the Roman numerals I, II, etc.; in this case the soi will be denoted as follows (II — 6 cm; I — 10 cm; 10 cm).[4] In the sod-podzolic zone, in view of the small thickness of the humus hori zons of sod-podzolic soils, water-deposited SM soils, beginning with thickly-deposited soils, may even predominate over primary-deposited ones.

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[4] On arable appendages the thickness of the upper layer will always correspond to the depth of plowin

Thus the proposed classification of water- posited soils reflects the thickness, properties d fertility of the deposited layer in compari- n with the separate genetic horizons of the il lying below the deposited layer, and in rticular with the humus horizon, this being e most fertile horizon and the one situated mediately below the water-deposited layer. also considers the soil group and degree of ater-erosion. An example of how water-de- sited soils are classified on this basis is given Table 1, the soils in this case being sod- edium-podzolic.

With the present plowing depth of 20-22 cm e plowed layer in thinly-deposited soils of the t gradation consists of a humus horizon and water-deposited layer. The sub-plowed yer is a humus horizon with a thickness of t more than half its original thickness (i. e, t more than half the plowed layer).

In thinly-deposited soils of the 2nd gradation e plowed layer consists of a water-deposited yer and to a lesser extent of a humus horizon. he sub-plowed layer is a humus horizon with a ickness between one-half and its full thickness.

In medium-deposited soils of the 1st grada- on the sub-plowed layer is also a water-de- sited layer with a thickness of not more an 1/2 A_2.

In medium-deposited soils of the 2nd grada- on the sub-plowed layer is a water-deposited yer with a thickness of from half the podzolic rizon to its full thickness.

In thickly-deposited soils of the 1st gradation e sub-plowed layer is a water-deposited layer th a thickness more than horizon A_2, but not ore than the sum of horizons $A_2 + 1/2\ B_1$. ith the 2nd gradation of deposition the sub- owed layer is a water-deposited layer with a ickness more than $A_2 + 1/2\ B_1$, but not more an the sum of horizons $A_2 + B_1$.

In very thickly-deposited soils of the 1st adation the sub-plowed layer is a water-de- sited layer with a thickness more than A_2 + , but not more than $A_2 + B_1 + 1/2\ B_2$. With e 2nd gradation of deposition the sub-plowed yer is a water-deposited layer with a thick- ss more than $A_2 + B_1 + 1/2\ B_2$, but not more an $A_2 + B_1 + B_2$.

In buried soil the sub-plowed layer is a water- posited layer with a thickness of more than + $B_1 + B_2$, i. e., more than the whole soil ofile without the humus horizon.

We distinguish two basic groups of water- posited soils: 1) water-depositing occurs at e expense of the humus horizon, such soils ing characterized by high fertility; 2) water- positing occurs not only at the expense of the humus horizon (the plowed layer of non-eroded soils), but also of the lower-lying horizons and even subsoil (plowed layers of eroded soils or from material carried up from places hollowed out by water). These soils are of poor fertility. To distinguish them from the former we denote them by the index letters SM (water-deposited SM).

In both groups two sub-groups may be encountered: I — the depositing occurs on non-eroded soil and II — soil which has already eroded is subjected to depositing.

In the first case, in addition to the degree of deposition, the soil group, subgroup, species and variety are indicated; in the second case, the degree of soil erosion is also shown. The supplementary designations "secondary-deposited" (2) or "eroded-deposited" (12) we regard as superfluous; they need not in our view be included in the classification for subgroup II of water-deposited soils. The degree of soil erosion should be shown in the classification of deposited soils, as should the genetic designation of the soil. The classification of water-deposited soils cannot be isolated from that of soils, i. e., the classification of soil groups and water-eroded soils (if the latter are subjected to depositing).

In the classification of water-deposited soils (subgroup II), in which the deposited layer lies on water-eroded soil, there is no possibility of comparing the thickness of the deposited layer with the original thickness of the horizons of the eroded soil, for beginning with the group of thinly-eroded soils it consistently diminishes. Instead, as a result of water-erosion and re-plowing the separate horizons are obliterated, for the plowed layers in water-eroded soils are a mixture of two, three or even four genetic horizons. For example, in thickly-deposited sod-podzolic soils in the plowed layer consists of a mixture of the remains of horizons $A_1 + A_2 + B_1$ and of part of horizon B_2. Hence, in classifying soils deposited by water on to water-eroded soils the former thickness of their genetic horizons, of the horizons of similar normal soils has to be taken into account; or one should take the thickness of the root-bearing layer as 100 cm, divide it into parts which are multiples of the thickness of the plowed layer and compare the thickness of the water-deposited layers with them (Sobolev 16-17). In this case we obtain the following subdivision: thinly-deposited soils have a deposited layer thickness of 20-25 cm; medium-deposited, 25-50; thickly-deposited, 50-75; and very thickly-deposited, 75-100 cm. When the thickness of the deposited layer is greater than 100 cm, i. e., approximately equal to the thickness of all the genetic horizons — of the whole soil profile (sod-podzolic zone) — and when the soil buried under the alluvium barely affects the fertility

Table 1

Classification of water-deposited soils. Sod medium-podzolic clay loams (G. A. Presnyakova)

Degree of deposition	Thickness of deposited layer	Gradation of deposition	Thickness of deposited layer
Thinly-deposited Thinly-deposited SM[a]	Not more than thickness of humus horizon[b]	1	Not more than 1/2 thickness of humus horizon
		2	From 1/2 to full thickness of humus horizon
Medium-deposited Medium-deposited SM	More than thickness of humus horizon, but not more than thickness of sum of horizons $A_1 + A_2$	1	More than thickness of horizon A_1, but not more than $A_1 + 1/2\ A_2$
		2	More than thickness of sum of horizons $A_1 + 1/2\ A_2$, but not more than $A_1 + A_2$.
Thickly-deposited Thickly-deposited SM	More than thickness of' sum of horizons $A_1 + A_2$, but not more than sum of horizons $A_1 + A_2 + B_1$	1	More than thickness of sum of horizons $A_1 + A_2$, but not more than $A_1 + A_2 + 1/2\ B_1$.
		2	More than thickness of sum of horizons $A_1 + A_2 + 1/2\ B_1$, but not more than $A_1 + A_2 + B_1$
Very thickly-deposited Very thickly-deposited SM	More than thickness of sum of horizons $A_1 + A_2 + B_1$, but not more than sum of horizons $A_1 + A_2 + B_1 + B_2$ (whole soil profile)	1	More than thickness of sum of horizons $A_1 + A_2 + B_1$, but not more than $A_1 + A_2 + B_1 + 1/2\ B_2$
		2	More than thickness of sum of horizons $A_1 + A_2 + B_1 + 1/2\ B_2$, but not more than $A_1 + A_2 + B_1 + B_2$
Buried soil or deposit[c]	More than thickness of sum of horizons $A_1 + A_2 + B_1 + B_2$ (whole soil profile)	—	—

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[a] In water-deposited SM soils the genetic origin of the separate deposited layers and their thickness should be indicated in centimeters.

[b] At the present time, when plowing is to a depth of 20-22 cm and the plowed layer of sod medium-podzolic soil, apart from the humus horizon, contains part of the plowed podzolic horizon, on plowed appendages the thickness of the arable layer is taken into account.

[c] Soils of this degree of deposition in the sod-podzolic zone most often have a deposit consisting of layers deposited from plowed horizons of soils of a various degree of water-erosion.

of the new formation, the buried soil or deposit should be distinguished as a fifth degree of deposition.

The same principle of subdividing water-deposited soils can be applied in areas where the soils have a thick humus horizon.

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METHODS

CHARACTERISTIC FEATURES OF THE CONTENT AND COMPOSITION OF HUMUS IN SOILS OF THE KARELIAN ASSR

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Much attention is being given to the study of the content and composition of humus in soils. The fundamental laws governing the accumulation of humus and nitrogen in the soils of different geographical zones have been established by a number of authors (1, 2, 3, 4, 5, 9). However, little data are as yet available on the content of organic matter in the podzolic soil group and the nature of the change it undergoes (6, 7). In this respect there has been almost no study of the soils of Karelia.

This paper furnishes data concerning contents of humus and nitrogen, and also concerning the composition of the humus in the basic and most widespread types of soils in Karelia. The soil samples were collected by us in the summer of 1955 and 1956. The humus composition was studied by Tyurin's method (8) with small changes. For instance, 0.02 N H_2SO_4 was used for decalcification of the soil, not 1 N NA_2SO_4. Total nitrogen content was determined by Kjeldahl's method, and particle-size analysis by Kachinskiy's. Humus and nitrogen contents were determined according to genetic horizons, bulk densities of the soil being taken into account. The data obtained are given in Tables 1 and 2 and in Figure 1.

As regards humus composition and its distribution in the profile all the soils we studied can be divided into three groups: the first consists of sand and sandy-loam podzols, with the humus-illuvial process showing differing degrees of definition; the second consists of podzolic, clay loam and sod-podzolic soils, and the third, of podzolic soils which have been brought under cultivation and which differ in texture and genesis.

The sandy and sandy loam podzols, which are most widespread in northern and central Karelia, have developed on deposits of acid Fenno-Scandian moraine and on fluvioglacial alluvia. These soils have a characteristic morphological structure. Below a forest litter of varying thickness lies a podzolic A_2 horizon, under which is an illuvial horizon, ochreous cinnamon-brown in color, which gradually passes into the underlying parent material. The thickness of these horizons and the accun lation of humus in the illuvial horizon depends basically on the type of forest, with which the quantity and composition of deposited organic matter is associated, and the rapidity of its humification and mineralization. In pine forests with a white-moss floor, iron podzols from which a thin podzolic horizon. In pine red-huckleberry — white moss forest, humic iron podzols develop with tongue-like intrusio with a thin podzolic horizon, and little accum lation of humus in the illuvial horizon, becaus of the small amount of litter. A soil of this type is described below.

Profile 213. Located on a flat hilltop cover with pine woods and Iceland moss. Cut-over pine, second growth ten years old, whole are covered with Iceland moss, occasional red hu berry and green mosses.

Ao, 0-2 cm. Litter of Iceland moss, semidecomposed.

A_2, 2-7(25) cm. Whitish loose sand. Tran tion sharp, along an irregular line.

B_1, 7(25)-19(26) cm. Ochreous, sandy loam, with boulders and gravel.

BC, 19(26)-50 cm. Ochreous-yellowish, sandy, fine-grained, gravelly. Gradual trans tion to horizon C at 50-70 cm., brownish with greenish tint, silty sand, size of particles va able with gravel and boulders.

Under spruce-pine and pine forests with b berry and green moss, where there is more moisture, the sandy loam parent materials a covered by iron-humic podzolc, with a large accumulation of humus in the illuvial horizon and deep penetration of humic acids downwar through the profile.

Profile 38. Located south of the city of Medvezhegorsk, on the upper part of a bould

Table 1

Particle-size analysis of soils of Karelia developed on different soil-forming parent materials

Profile No.	Soil and site of sample collection	Horizon	Depth, cm	skeleton, %	Particle diameters, mm, as % of earths					
					1—0.25	0.25—0.05	0.05—0.01	0.01—0.005	0.005—0.001	<0.001
16	Iron-humic podzol, sandy, developed on gravelly sands Prionezhskiy district	A_2	5—10	2	37	40	17	1	2	3
		B_1	10—20	19	36	36	23	1	1	4
		B_2	25—30	36	50	28	15	2	2	3
		BC	50—60	36	40	33	15	4	6	2
		C	95—100	47	61	28	8	1	1	1
11	Sandy loam stony moraine. Prionezhskiy district		7—15	21	36	36	16	6	3	3
324	Sod-podzolic, sandy loam on silty sandy loams. Sortaval'skiy district	A_1	0—5	1	1	57	26	3	6	7
		A_1	5—15	1	2	60	24	1	3	10
		B_1	17—30	None	2	60	20	5	4	9
		BC	40—50	"	1	67	16	7	2	7
4	Sod-podzolic gleyed, clay loam on stratified clay loams. Olonetskiy district	A_1	0—12	"	3	44	18	12	12	11
		B_1	25—35	"	1	39	26	11	9	14
		B_2	40—50	"	10	23	16	14	19	18
		BC	60—70	"	15	50	9	10	9	7
12	Podzolic, clay loam on clay loam moraine. Prionezhskiy district	A_2	5—10	"	17	30	24	11	11	7
		B_1	30—40	16.7	2	21	30	23	18	6
		BC	50—60	None	51	10	16	14	6	3
61	Sod-gleyed, podzolized, clay loam on clayey moraine. Pudozhskiy district.	A_2	11—15	"	35	31	11	10	7	7
		A_q	15—25	"	1	20	14	5	19	41
		B_q	42—46	"	2	12	11	14	18	43
		C	95—100	"	0,4	33	9.1	13	28	46.2

pe covered with spruce woods of site qual- III. Whole area covered with bilberry l green mosses.

Ao, 0-4 cm. Peaty litter, semidecomposed.

A_2, 4-20 cm. Light-grey (whitish) sandy, ticles of different sizes, loose.

BH, 20-33 cm. Dark cinnamon-brown- wn, sandy, coarse-grained with gravel.

B_2, 33-75 cm. Coffee cinnamon-brown, dy, with cemented ortsand patches; many lders.

C, 75 cm and below. Brownish-grey sandy m, gravelly, with blue-grey and rust- ored patches, strongly compacted.

The greatest quantity of humus accumulates odzols of the humic-illuvial type, beneath ests with water-logged soils. A morphologi- description of a peat-podzol of the humus- vial type is given below.

Profile 364. Located on a gentle, slope on undulating plain. Pine forest of site quality some undergrowth: marsh rosemary, bog rtleberry, bilberry, green mosses on hillocks, sphagnum between hillocks.

A'o, 0-6 cm. Cover of sphagnum and long-stemmed mosses.

A''o, 6-12 cm. Dark cinnamon-brown (almost black) peat, well decayed.

A_2, 12-19 (20) cm. Brownish-whitish, sandy, medium-grained, loose.

BH' 18(20)-24(26) cm. Dark cinnamon-brown, sandy, gravelly.

BH^2, 24(26)-38 cm. Cinnamon-brownish, sandy.

B_2, 38-52 cm. Brown with cinnamon-brown patches, sandy, gravelly.

BC, 52-80 cm. Light-brown ochreous blue-grey patches, sandy loam, gravelly.

C, 80-30 cm. Light blue-grey, sandy loam, gravelly, with rust-colored patches.

Up to 9% of the humus accumulates in the illuvial horizon of these soils. Characteristic is the accumulation of organic matter in horizon A_0 in the form of slight-humified forest litter.

Table 2

Humus and nitrogen contents of basic types of soils in Karelia

Profile No.	Soil, land use, and site of sample collection	Horizon	Depth, cm	Humus content metric tons/ha	% of total content	Nitrog. content metric tons/ha	% of total content
1	Iron podzol, thin humus, sandy beneath pine forest. Kondopozhskiy district	A_0	0—2	41.3	80.5	0.48	50.0
			2—50	10.0	19.5	0.47	50.0
			Total	51.3	100.0	1.95	100.0
213	Humic-iron podzol, sandy. Pine stand. Iceland moss. Suoyarvskiy district.	A_0	0—2	56.9	64.9	0.76	53.4
			2—50	30.9	35.1	0.64	46.6
			Total	87.8	100.0	1.40	100.0
38	Iron-humic podzol, sandy, beneath pine-spruce forest with bilberry. Medvezh'yegorskiy district	A_0	0—4	47.9	42.5	1.64	41.2
			4—50	64.8	57.5	2.34	58.8
			Total	112.7	100.0	3.98	100.0
303	Iron-humic podzol, sandy loam. Pine forest, red huckleberry and green moss. Biovanets.	A_0	0—2	22.6	27.0	0.35	23.3
			2—50	61.4	73.0	1.15	76.7
			Total	84.0	100.0	1.50	100.0
364	Peaty podzol, humic, sandy. Pine forest, red huckleberry, longstem moss. West of Loukha.	A_0	0—12	221.4	56.6	4.55	—
			12—50	169.6	43.4	—	—
			Total	391.0	100.0	—	—
16	Podzolic, clay loam. Mixed forest with well-developed herbaceous vegetation. Kondopozhskiy district.	A_0	0—5	60.0	60.8	1.50	37.8
			5—50	39.4	39.2	2.50	62.2
			Total	100.6	100.0	4.00	100.0
56	Podzolic, passing to sodded fine clay loam. Spruce forest varied herbage. Pudozhskiy district.	A_0	0—5	41.7	30.0	1.40	33.0
			5—50	97.0	70.0	2.80	67.0
			Total	138.7	100.0	4.00	100.0
197	Sod-podzolic on schungite moraine, under sparse birch stand. Spasskaya Bay.	A_0	0—3	33.3	20.0	0.59	12.0
			3—50	135.4	80.0	4.35	88.0
			Total	168.7	100.0	4.94	100.0
9	Humus-podzolic, iron-humic beneath spruce and bilberry. Kurkioki	A_0	2—7	37.5	26.2	1.33	26.1
			7—23	105.7	73.8	4.15	73.9
			Total	143.2	100.0	5.48	100.0
324	Sod-podzolic, sandy loam. Idle land. Sortavalskiy district.	A_{11}	0—17	67.6	79.0	2.7	71.0
			17—50	17.6	21.0	1.1	29.0
			Total	85.2	100.0	3.9	100.0
21	Podzolic, cultivated, on sandy loam moraine. Idle land.	A_{11}	0—15	66.0	92.0	3.8	90.0
			15—50	6.0	8.0	0.4	10.0
			Total	72.0	100.0	4.2	100.0
4	Sod-podzolic gleyed, clay loam. meadow, with Deschampsia. Olonetskiy district.	A_1	0—22	119.4	79.0	6.3	92.0
			22—50	32.5	21.0	0.5	8.0
			Total	151.9	100.0	6.7	100.0

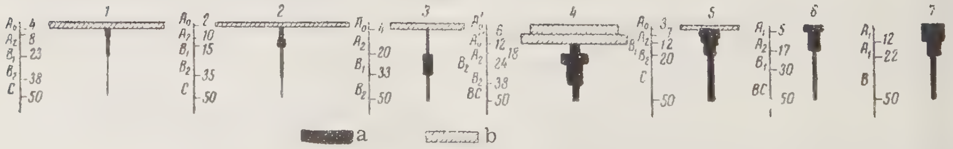

Fig. 1. - Content of organic matter in litter (b) and mineral horizons (a) of soils in Karelia.

1 - Profile 1. Iron sandy podzol, pine-stand - red huckleberry; 2 - Profile 213. Humic-iron podzol, pine-stand -- Iceland moss; 3 - Profile 38. Iron-humic podzol, pine-spruce forest -- bilberry; 4 - Profile 264. Peaty, humus-illuvial podzol, pine forest, site quality V -- long-stem moss; 5 - Profile 197. Sod-podzolic on schungitic moraine beneath sparse birch stand; 6 - Profile 324. Sod-podzolic, cultivated, idle land; 7 - Profile 4. Sod-podzolic gleyed, meadow, with Deschampsia.

This horizon may contain up to 80% of the total rganic matter in the soil (Profile 1, Table 2). We observed this sort of distribution of organic matter in a sandy iron podzol having a total ontent of organic matter not exceeding 50 metric tons per ha.

As the humic-illuvial process develops, the ontent of organic matter increases. Thus the umus content in humic-iron podzols (Profile 13) is 88 metric tons per ha; in iron-humic odzols (Profile 38) it is 112 metric tons per a; and in humic-illuvial podzols (Profile 364), 90 metric tons per ha. In a humic-iron podzol he content of organic matter in the mineral orizons is three times as great as that in an ron podzol, and in a iron-humic podzol, it is ive times as great. In a podzol of the humic-illuvial peaty type (Profile 364), organic matter ccumulates not only by reason of humus accumulation in the mineral horizons but also by hickening of the peat litter. Figure 1 shows he way in which organic matter is distributed n the litter and mineral horizons of the soils nder study.

Thus, a characteristic feature of this group f soils is the accumulation of organic matter n horizons A_0 and B_1 and the very small mount thereof in horizons A_2 and B_2. Most of hese soils have a shallow profile: at a depth f 30-40 cm the humus content is not more than .3%-0.5%.

The other group of soils — podzolic clay oams and sod-podzolic soils — are found mainly in south and east Karelia on local clay loam moraines and lacustrine-glacial deposits. Mixed forests with well-developed herbaceous egetation grow on these soils. They often have gricultural crops. In sod-podzolic soils we bserved the formation of an accumulative A_1 orizon. The strongly podzolic soils transitional to sod-podzolic, which are widespread n Pudozhskiy district, may serve as an example. Profile 56 is characteristic.

Profile 56. Located on a gently undulating plain under a spruce forest of site-quality III with a young growth of mountain ash and wild rose, a well-developed herbaceous vegetation f Acanthus, stone-bramble, Majanthemum, lily-of-the-valley, and other plants, and with ccasional hypnaceous moses.

A_0, 0-5 cm. Litter, slightly decomposed.

A_1A_0, 5-6 cm. Dark-grey fine clay loam, mall-grained, loose.

A_1, 6-7 cm. Grey, fine clay loam, grainy-scaly.

A_2A_1, 7-14 cm. Light-grey, fine clay loam, loose.

A_2, 14-33 cm. Brownish-whitish, medium clay loam, scaly-plates, compact.

A_2B_1, 33-50 cm. Brown with whitish tongue-like intrusions of the A_2 and rust-colored patches, compact.

B_1, 50-74 cm. Brown, fine clay loam, cubic-layered, compact. Transitions between horizons gradual.

In the trans-Onega region unusual sod-podzolic soils on schungitic moraine are widespread.

Profile 197. Located at the crest of a ridge under a sparse stand of birch. Under growth of alder, mountain ash, and bird-cherry. Well-developed herbaceous vegetation of Calamagrostis, stone-bramble, field vetch, and others. Green mosses in places. Many boulders on surface.

A_0, 0-3 cm. Forest litter of leaves and herbs, loose, semidecomposed.

A_1A_2, 3-7 cm. Grey, clay loam, with sprinkling of silica, many fragments of schungitic schist.

A_2B_1, 7-12 cm. Brownish-grey, clay loam, gravelly.

B_1, 12-27 cm. Dark-brown, clay loam, gravelly with boulders.

C, 27-75 cm. Dirty-grey, clay loam with schungitic fragments.

In conclusion we shall describe the humus podzolic, iron-humic soils found in southwest Karelia.

Profile 9. Located on the lower part of a gentle slope under a spruce forest with bilberry and with green mosses.

A_0, 0-7 cm. Dark cinnamon-brown forest litter, well decayed.

A_1, 7-15 cm. Dark grey with cinnamon-brown tint, sandy loam.

BH, 15-35 cm. Ochreous cinnamon-brownish, sandy loam with boulders.

B_2, 35-55 cm. Cinnamon-brownish to brown, sandy loam, many boulders. Gradual transition to underlying parent material.

Cq, 55 cm and below. Light brown with rusty patches, sandy.

In northern and central Karelia humic-illuvial podzols form on coarse-textured parent materials under spruce forests. In the soils of the southwest part the humus is distributed evenly through the profile, gradually decreasing with depth. The principal humus content is concentrated in the mineral horizons. The litter contains only about 20%-30% of the total organic matter (profiles 56, 9, 197; Table 2). The total humus content in these soils amounts to 140-168 metric tons per ha. Peculiar podzolic soils in Kondopozhskiy district (Profile 16), which show signs of gleying and have developed on boulder-free loam, constitute an exception. In these the bulk of the organic matter takes the form of a strongly humified forest litter containing about 45% humus. The mineral horizons contain only small quantities of humus; e. g., at a depth of 15-20 cm., it amounts to only 0.3%.

Cultivated podzolic soils are located mainly in the southwestern and southeastern Karelia. The total humus content in these soils depends on their texture and extent of cultivation. The humus content is higher in fine-textured soils than in coarse. Thus in sod-podzolic gleyed soils the total humus content is as much as 150-180 metric tons per ha (Profiles 4, 61: Table 2). In coarse-textured cultivated soils the content does not exceed 70-85 metric tons per ha (Profiles 21, 324; Table 2).

In podzolic soils under agricultural crops, most of the humus (60%-80% of the total in clay loams and 90% in sandy loams) is contained in the plow layer. The nitrogen content and its distribution in the soils is closely associated with the organic matter. The sandy and sandy loam podzols (the first group of soils) are very poor in nitrogen. Their nitrogen content does not exceed 2-3 metric tons per ha, and in the iron podzol it is less than one metric ton per ha. Up to 50% of the total nitrogen is contained in the mineral horizons. This goes to show that the humus of the mineral horizons is much richer in nitrogen than the organic matter of the litter, where the ratio of carbon to nitrogen is widest (up to 45).

Total nitrogen content is somewhat higher in sod-podzolic and podzolic loams (the second group of soils), where they amount to 4-5.5 metric tons per ha. Most of the nitrogen (60%-80%) in these soils is contained in the organic matter of the mineral horizons.

Richest in nitrogen are the cultivated clay loams (the third group), which contain 6-11 metric tons per ha. Coarse-textured soils contain less nitrogen than clay loams — about 4 metric tons per ha, but their nitrogen content is considerably greater than in the corresponding forest soils.

The three groups of soils differ not only as regards total content and distribution of organic matter, but also as regards humus composition.

The data in Tables 3 and 4 testify to the high mobility of the humus in the sandy and sandy loam podzols. Particularly mobile is the humus in the illuvial horizons of the sandy soils, where the non-hydrolyzable residue com prises only 8%-20% of the total humus content (Profiles 213, 38, 364; Table 3). In the podzolic A_2 horizon, the humus is still more mobile.

The humus of the sandy loam podzols is rather less mobile; here the non-hydrolyzable residue equals up to 37% of the total humus content (Profile 303; Table 3). Characteristic of the humus in all the soils of this group is the total absence of humic and fulvic acids bound to calcium (Fraction II) and a very smal content or total absence of humic and fulvic acids firmly bound to sesquioxides (Fraction III). In sandy and sandy loam soils, this fraction of humic acids is as a rule absent.

Thus, in the podzols, both humic and fulvic acids are present in mobile forms bound to sesquioxides or in a free state. The content of fulvic acids is two or three times that of humic acids, reaching 50% of the total humus content. As the depth increases, the relative content of fulvic acids in the humus rises, and that of humic acids declines. A characteristic index of the humus composition is the ratio of fulvic acids. In the mineral horizons of podzols it is always less than one, and as the dept increases it falls to 0.2-0.1 (Profiles 364, 213; Table 3).

The organic matter of the forest litter differs considerably in composition from the humus of the mineral horizons, and is governe by the composition of the plant residues, i. e, by the type of forest. Characteristic of all forest litters is their high content of non-hydr lyzable residue — up to 70% (Profile 261; Table 3); the content of organic matter in the litter changes according to the degree of decomposition.

A litter in a more advanced stage of decomposition contains less non-hydrolyzable residue, for the organic matter becomes mor mobile as it humifies. Thus, in a podzol of the humic-illuvial type, the content of non-hydrolyzable residue in horizon A_0 (0-6 cm) i 54% of the total humus, whereas in the more mineralized part of the same horizon (6-12 cm it is 39% (Profile 364, Table 3).

The ratio between humic and fulvic acids is not the same in the litter as in mineral hori zons. It is almost always greater than one, and in podzol of the humic-illuvial peaty type (Profile 364) it is about three. Thus in the litter there is a considerable amount of humic acids, which here consist mainly of brown

Table 3

Composition of humus of Karelian soils developed on coarse clay loams soils (according to I. V. Tyurin's chart)

Profile No.	Soil and land use	Horizon	Depth, cm	In % of initial soil		C/N	In % of total organic carbon of initial soil													
				Total organic carbon (C)	Total nitrogen (N)		Wax-resins	Hydrolyzed by 0.02 N H_2SO_4	Humic acids				Fulvic acids					Substances, hydrolyzed by 1 N H_2SO_4	Non-hydrolyzable residue	C of humic acids / C of fulvic acids
									I	II	III	Sum	Ia	I	II	III	Sum			
1	Iron podzol, sandy. Pine-stand.	A_0	0—4	41.40	0.92	45	6	Not det'd.	11	Not det'd.		11	1	7	Not det'd.		8	Not det'd.		
		A	4—8	0.30	0.03	12	4	"	27	"		27	7	10	"		17	"		
		B_1	8—20	0.10	0.02	7	3	"	11	"		11	5	44	"		49	"		
213	Humic-iron podzol, sandy. Pine-stand — Iceland moss.	A_0	0—2	33.10	0.77	43	29	0.4	8	4	1	13	0.2	9.(	None	1	10.2	2	45.4	1.3
		B_1	10—15	1.15	1.07	16	7	9	16	None	3	19	25	14	"	0.4	39.4	15	10.6	0.5
		B_2	35—45	0.23	None		15	5	None	4	None	4	40	None	"	1	41	13	22	0.1
38	Iron-humic podzol, sandy.	A_0	0—3	22.09	1.30	17	20	2	13	1.6	0.4	14	None	11	6	1	18	1	45	0.8
		B_1	25—35	1.53	0.12	13	9	15	11	None		11	12	10	None	4	26	16	24.7	0.4
261	Humic-iron podzol, sandy loam. Spruce-pine forest, bilberry — green-moss.	A_0	0—3	34—78	0.82	44	16	1	8	"		8	1	None	2	1	5	4	66	1.8
		B_1	10—16	1.35	0.07	18	4	7	11	5		16	29	21	None	2	52	3	18	0.3
		B_2	16—26	0.55	0.04	14	4	8	15	None		15	26	8		6	40	9	24	0.4
303	Iron-humic podzol, sandy loam. Pine forest, red huckleberry — green-moss.	A_0	0—2	22.63	0.60	28	28	1	10	"	1	11	1	11	1	4	17	3	40	0.7
		B_1	5—13	1.55	0.09	17	6	8	12	None		12	19	1	5	4	29	9	35	0.4
		B_2	13—23	0.47	0.06	8	1	11	14	"	1	15	18	8	None		26	8	39	0.6
364	Peaty podzol, humic, sandy. Pine forest, site quality V, long-stem moss.	A_0	0—6	29.81	1.05	28	15	1	17	"	1	18	1	None		5	6	6	54	3.3
		A_0	6—12	41.70	1.48	28	23	1	25	"	2	27	1	"	3	6	10	2	39	2.8
		A_2	12—18	1.21	—	—	19	4	27	1		28	5	"	4	3	12	1	36	2.4
		B_1	18—24	4.72	—	—	2	11	26	None		26	26	15	None	1	52	1	8	0.5
		B_2	24—35	2.51	—	—	1	19	13	"		13	36	19	"	1	56	3	8	0.2
		BC	45—50	0.83	—	—	2	34	7	"		7	23	16	"	1	40	4	13	0.2

Table 4

Podzolic and sod-podzolic soils of southern Karelia

Profile No.	Soil and land use	Horizon	Depth, cm	In % of initial soil		$\frac{C}{N}$	In % of total organic carbon of initial soil													
				Total organic carbon (C)	Total nitrogen (N)		Wax-resins	Hydrolyzed by 0.02 N H_2SO_4	Humic acids				Fulvic acids					Substances, hydrolyzed by 1 N H_2SO_4	Non-hydrolyzable residue	$\frac{\text{C of humic acids}}{\text{C of fulvic acids}}$
									I	II	III	Sum	Ia	I	II	III	Sum			
	According to I. V. Tyurin's chart																			
16	Podzolic, clay loam. Mixed forest.	A_0	0—5	23.26	0.94	25	15	1	12	None	1	13	1	2	1	4	8	5	58	1.6
		A_2B_1	7—15	1.19	0.08	15	9	7	20	"	1	21	9	1	None		10	6	27	2.1
		B_1	30—40	0.19	0.03	7	18	3		"			22	21	"	7	50	8	21	—
56	Podzolic, fine clay loam. Spruce forest.	A_0	0—5	16.1	0.94	19	13	1	10	8	3	21	None	10	"	4	14	2	49	1.5
		B	15—25	0.39	0.08	6	13	4	21	None	6	27	1	2	13	3	19	6	31	1.6
197	Sod-podzolic on schungitic moraine beneath sparse birch stand.	A_0	0—3	21.6	0.64	35	9	1	6	2	2	10	1	10	4	1	16	4	60	0.6
		A_1	3—7	3.54	0.18	19	4	3	18	None	2	20	2	12	None	3	17	6	50	1.2
		B_1	7—12	2.62	0.21	12	6	3	22	1	3	26	1	5	3	1	10	7	48	2.6
		B_2	15—20	1.50	0.09	16	2	6	17	None	2	19	15	14	None	2	31	14	28	0.7
		C	30—40	0.75	0.06	13	5	6	12	None		12	"	26	"	3	29	8	40	0.4
9	Humic-podzolic, iron-humic. Spruce-green moss.	A_0	2—7	8.75	0.53	17	10	3	21	None	3	24	2	21	"	2	25	3	25	1.9
		A_1	7—15	4.14	0.37	11	7	5	25	2	7	34	4	16	None		20	2	32	1.7
		B	18—23	2.16	0.16	14	13	15	13	None	3	16	20	14	None	3	37	4	15	0.5
	Basic types of cultivated soils.																			
25	Sod-podzolic, sandy loam, cultivated. Clover and timothy of 2nd crop year.	$A_п$	0—18	3.60	0.22	16	12	2	23	4	2	29	2	2	7	1	12	6	39	2.4
		B_1	25—35	0.40	0.05	9	29	10	None	11	None	11	None	19	None	1	20	15	15	0.6
21	Podzolic, cultivated, on sandy loam moraine.	$A_п$	5—15	3.30	0.35	10	4	6	32	None	5	37	5	10	"	3	18	4	31	2.1
		B_1	25—35	0.77	0.08	9	13	22	10	"	3	13	8	28	None		36	4	12	0.4
16	Sod-podzolic-gleyed, fine clay loam, cultivated. Clover, one yrs. hay cut.	$A_п$	0—20	2.70	0.28	9	5	1	32	"	3	35	5	21	None	2	28	2	29	1.3
		B_1	23—31	1.03	0.10	10	10	2	16	"	5	21	14	12	4	4	34	4	29	0.5
61	Sod-gleyed, fine clay loamy, cultivated.	A_d	0—7	20 9	0.77	27	6	1	10	"	1	11	1	8	None	5	14	4	64	0.8
		A_1	11—15	6.46	0.55	12	8	2	21	"	6	27	3	7	"	4	14	3	46	2.0
		B_1	15—25	2.35	0.19	13	12	7	20	"	6	26	1	2	6	3	12	3	40	2.1

ulminic" acids.

The podzolic and sod-podzolic soils (second roup) differ from the sandy podzols (first roup) in regards to the humus of their mineral orizons in that the humus is less soluble and is nore firmly bound to the mineral part of the oil. The non-hydrolyzable residue in these oils comprises 40%-50% of the total quantity f humus (Profiles 16, 197; Table 4). The low ontent of non-hydrolyzable residue (15%) in orizon B of the humic-podzolic soil (Profile) is explained both by the coarse texture of he soil concerned and by the greater mobility f the humus in the illuvial horizons.

Another special feature of the humus compo- ition of clay loam soils is the different ratio etween humic and fulvic acids. In the A_1 ac- umulative horizon, and sometimes in horizon $_1$ of soils developed on mineralogically richer arent materials (Profiles 56 and 197; Table), humic acids predominate over fulvic and he ratio of humic to fulvic acids is always reater than one. In sod-podzolic soil de- eloped on schungitic moraine, it reaches 2.6 Profile 197, Table 4). The marked predomin- nce of humic over fulvic acids in the upper orizons is characteristic of these soils, it s apparently attributed to the high mobility f the fulvic acids and their penetration to he underlying horizons.

The humus composition in the lower hori- ons of clay loam soils is similar to that of he corresponding horizons of the sandy pod- ols. Fulvic acids predominate, and the umus is marked by greater mobility than in he accumulative horizons.

Finally, another special feature of the humus f soils developed on fine-textured parent ma- erials is its increased content of humic acids irmly bound to sesquioxides — up to 6%-7% Profiles 56 and 9; Table 4). In soils de- eloped on mineralogically richer local noraines, humic and fulvic acids of Fraction I bound to calcium are present (Profiles 56 nd 197; Table 4).

The humus of the cultivated soils concentrated nainly in the south of Karelia is similar in com- osition to that of the non-cultivated sod-pod- olic soils. As regards to both composition and otal content of humus, the profile of these cul- ivated soils falls into two distinct parts: (1) a low layer A_p; and 2) all lower horizons. In he humus of the plow layer, just as in the ac- umulative horizons of the sod-podzolic soils, umic acids predominate over fulvic. Even in he sandy loam soils, the non-hydrolyzable res- due reaches 30%-40% of the total carbon (Pro- iles 325 and 21; Table 4), and in the clay loam oils the figure is 65% (Profile 61; Table 4). n the plow layer of well-cultivated soils, humic nd fulvic acids bound to calcium appear in the humus (Profile 325; Table 4).

The humus of the sub-low layers, particularly in soils developed on coarse-textured parent materials, is very mobile, and fulvic acids predominate in it. An exception is the sod-podzolic gleyed soil (Profile 61; Table 4) developed on a mineralogically rich clay-loam parent material.

Conclusions

1. In regards to the total content and composition of humus, the Karelian soils studied can be divided into three groups. First: sandy and sandy loam podzols with the humus-illuvial process defined to varying degrees. In these podzols most of the organic matter (50%-80%) is concentrated in horizon A_0, and the humus content in the mineral horizons depends upon how well-pronounced is the humus-illuvial process. Second: podzolic clay loam and sod-podzolic soils, in which more than half (70%-80%) of the organic matter is in the mineral horizons, because of the development of the sod process in these soils and their increased clay content. Third: cultivated podzolic soils of varying texture, in which most of the humus (60%-80%) is contained in the plow layer. Total humus here is greater, the more intensive the cultivation of the soil and the finer its texture.

2. The humus of all the soils studied is very mobile. The most mobile is the humus of the illuvial horizons of the sandy podzols.

3. In the humus of the podzols there is a marked predominance of fulvic acids in the free state or bound to mobile forms of sesquioxides (Fraction I).

4. The composition of humus in the sod-podzolic and podzolic clay loam soils varies according to position in the profile. Humic acids, mainly in the form of brown "ulminic" acids (Fraction I), predominate in the humus of the A_1 accumulative horizon, and sometimes in the B_1 horizon, of soils developed on mineralogically rich parent materials. The humus of these horizons is more firmly bound to the mineral part of the soil. But the lower horizons of these soils differ little in their humus composition from the soils of the first group. The humus is more mobile and fulvic acids predominate.

5. In humus composition the plowed soils are similar to the non-cultivated sod-podzolic soils.

6. Richest in nitrogen are the cultivated clay loam soils, in which the total nitrogen

amounts to 7-11 metric tons per ha. These soils contain much more nitrogen than the corresponding forest soils.

The humus of the mineral horizons is richer in nitrogen than the organic matter of the litter.

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HUMUS COMPOSITION OF SOLONETZ SOILS OF THE CRIMEA

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The increased area of orchards and vineards in the Crimean region has made it ecessary to utilize the remaining land under ther crops more intensively, and also to bring ie solonetz area into cultivation. The latter an be intensively utilized after measures are aken to increase their fertility.

If the methods used for the melioration of olonetz soils are to be based on scientific rinciples, the genesis of the soils must be tudied: in particular there must be research ito the nature of their organic matter. For ieir purpose, in 1955-1956, we studied the huius in different solonetz soils in the Crimean egion. Objects of the study were solonetzes nd solonetzic soils of the Sivash, developed n yellow-brown loess-like clays: meadow olonchak-like solonetz, meadow-steppe solonhak-like solonetz, deep-plowed solonetz of ie same type, steppe dark-chestnut solonetzic oil, and also southern low-humus chernozem. 'he humus of the steppe solonchak-like solonetz f Kerch peninsula, developed on Tertiary (Sariatian) clay, was also analyzed.

We have dealt elsewhere (18, 19) with the haracteristic features of these soils, most of ie samples of which were obtained at solonetz ielioration stations.

Humus composition was studied by Tyurin's iethod (24). The following were isolated: a) rganic matter, extracted by a mixture of alohol and benzol; b) humic acids and fulvic cids, divided into two groups. The first roup consists of humic and fulvic acids bound o calcium, and also in the free state or bound o mobile sesquioxides, and the second group onsists of humic and fulvic acids bound to esquioxides; c) Substances of the non-hyrolyzed residue — "humins." The content of mobile" or "free" humic acid was also deermined (13).[1]

Information on the composition of humus in solonetz soils is extremely scarce. M. M. Kononova (10, 11) has established that the humic acid content in the humus of the Trans-Volga solonetz soils is small; it is higher in chestnut soils. The humus of solonetz soils is distinguished by high mobility because of exchangeable sodium. L. N. Aleksandrova (1) has shown that in solonetz soils there is movement of fulvic acids across the profile. I. I. Yemel'yanov (8) has demonstrated that humic acids are less and fulvic acids more abundant in the humic solonetzic varieties of the chernozems and dark-chestnut soils of Kazakhstan than in the non-solonetzic types.

It has been established that the humus of solonetz soils contains more fulvic acids than that of non-solonetzic steppe soils. But the question as to whether there are any differences in the humus of the various groups of solonetzes has not yet been elucidated.

The present research was aimed at establishing: a) special features of the humus of the Sivash solonetzes, moving from north to south and ranging from the most hydromorphic to the steppe varieties; b) differences in the humus of the solonetzes in two provinces — Kerch peninsular and Sivash; c) changes in the humus content of solonetzes after deep plowing.

Let us examine the analytical data relevant to the first of these questions (see Table 1).

As can be seen from Table 1, the humus content in the soils of the Sivash is no more than 2-3%. Of the Sivash solonetzes, the meadows contain the most humus — 2.53%. In the meadow-steppe solonetzes, the amount decreases to 1.88%, increasing in the steppe dark-chestnut solonetzic soils to 2.33%.

Humic acids are important in the make-up of the humus of the soils studied. What is unusual is that we do not find in these solonetzes any direct dependence between content of humus and quantity of humic acids. On the contrary

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[1] Analytical work performed by V.A. Khasapova.

Table 1

Humus composition in solonetz soils of the Crimea and of southern chernozem in % of total organic carbon of initial soil

Profile No.	Soil, location	Depth, cm	Total organic C in % of soil weight	Humus %	Humus composition								C of humins	Sum	Ratio of C of humic acids to C of fulvic acids	Ratio of C of humic acids to C of humins	C of "free" humic acids
					C of alcohol-benzol extract	C extracted in soil decalcification	C of humic acids, by groups			C of fulvic acids, by groups							
							I	II	Total	I	II	Total					
276	Meadow solonchak-like solonetz developed on yellow-brown loess-like clay. Sovkhoz "Molodaya gvardoua" Azov dist.	0—10	1.47	2.53	2.0	19.0	25.8	2.0	27.8	17.0	1.4	18.4	27.9	95.1	1.5	1.0	6.1
		20—30	1.32	2.27	3.0	25.8	23.5	2.3	25.8	15.9	1.5	17.4	26.5	98.5	1.5	0.99	2.2
		40—50	0.97	1.67	16.5	21.6	15.5	3.1	18.6	16.5	1.0	17.5	23.7	97.9	1.0	0.8	Trace
244	Meadow-steppe solonchak-like solonetz on yellow-brown loess-like clay. Sovkhoz "Krym," Dzhankoyskiy district.	0—10	1.09	1.88	5.5	12.8	30.3	3.7	34.0	18.3	2.8	21.1	24.8	98.2	1.6	1.3	11.9
		20—30	1.00	1.71	8.0	13.0	25.0	3.0	28.0	19.0	2.1	21.1	30.0	100.1	1.5	0.9	4.0
		30—40	0.93	1.60	6.4	8.7	21.5	2.1	23.6	16.1	2.1	18.3	35.5	92.5	1.3	0.6	Trace
206	Dark chestnut solonetzic soil. Voroshilov kolkhoz, Krasno-Perekopskiy district.	0—10	1.35	2.33	5.2	11.8	31.1	3.0	34.1	18.5	2.2	20.7	27.4	99.2	1.6	1.2	5.9
		20—30	0.96	1.66	5.2	16.7	23.0	2.1	25.1	16.6	2.1	18 7	34.4	100.1	1.3	0.7	1.0
		30—40	0.86	1.49	5.8	18.7	19.8	2.3	22.1	19.8	2.3	22.1	30.2	98.9	1.0	0.7	2.3
16	Southern slightly-humified chernozem on yellow-brown loess like clay. Azov district.	0—10	1.75	3.00	2.9	5.7	33.3	2.3	35.6	15.6	1.1	16.7	27.5	88.4	2.1	1.3	Trace
		24—34	1.06	1.82	2.8	12.3	37.7	2.8	40.5	17.0	0.9	17.9	26.4	99.9	2.2	1.5	None
		34—47	1.08	1.87	7.5	6.6	30.9	1.9	32.8	14.9	1.9	16.8	30.1	93.8	1.9	1.0	Trace
202	Steppe solonchak-like solonetz on Sarmatian clay. Kolkhoz "Put' k kommunizmu," Primorskiy district.	0—10	1.76	3.03	2.3	26.1	17.0	0.6	17.6	20.4	1.1	21.5	31.8	99.3	0.8	0.6	1.1
		20—30	1.56	2.68	1.9	13.0	17.3	1.9	19.2	22.4	1.3	23.7	37.2	98.0	0.8	0.5	0.6
		40—50	1.47	2.53	2.7	29.9	15.6	0.7	16.3	21.1	1.4	22.5	27.9	99.3	0.7	0.5	1.4
281	Deep-plowed meadow-steppe solonchak-like solonetz on yellow-brown loess-like clay. Kolkhoz "Krym," Dzhankoyskiy district. Samples taken one year after deep plowing.	0—10	0.70	1.21	8.6	11.4	12.8	2.9	15.7	15.8	1.4	17.2	38.6	91.5	0.9	0.4	1.4
		10—20	0.76	1.32	7.9	9.2	14.5	1.3	15.8	14.5	1.3	15.8	42.1	90.8	1.0	0.3	None
		20—30	0.82	1.42	7.3	2.4	19.5	2.4	21.9	18.3	1.2	19.5	40.2	91.3	1.1	0.4	Trace
		30—40	1.02	1.77	7.8	9.8	22.5	2.0	24.5	14.5	1.0	15.5	40.2	97.8	1.5	0.6	8.8

e least amount of humic acids (27.9%) was und in the richest humus meadow-solonetz, e greatest quantity (34%) was in meadow-eppe. Only the slight steppe solonetzic soils iowed a direct relationship between the connts of humus and humic acids.

In all the solonetzes and solonetzic soils of ie Sivash, unlike the same soils in other reions of the Union, humic acids predominate ver fulvic acids, although a certain increase the total content of the latter is to be oberved.

The content of humic and fulvic acids in all ie soils studied decreases with depth. Only in ie dark-chestnut solonetzic soil does the perentage of fulvic acids at a depth of 30-40 cm icrease somewhat.

The humus of the Sivash solonetzes and olonetzic soils is very mobile. This can be idged from the content of the "free" humic cid fraction dissolved directly in alkalis beore decalcification of the soil. Tyurin's exlanation of the increased content of the fracon is that it results from instability of the omplexes bound to sodium (23).

The mobility of the organic matter in the olonetzes varies. In the meadow solonetz, free" humic acid in the humus reaches 6%; in ie meadow-steppe solonetz, it rises to 11.9% ius comprising a third of all the fractions f humic acid. In the steppe dark-chestnut olonetzic soil, the content of "free" humic cid falls to 5.9%, because of a certain stailization of the humus. It is characteristic iat in the southern chernozem it disappears ltogether, a fact which coincides with Tyurin's ata (23). Thus the organic matter of the meaow-steppe solonetzes is the most mobile. The ontent of humins (organic matter firmly bound the mineral part of the soil) increases in ie deeper layers to 24%-35% (except for the eadow solonetz).

The forms of the link between the organic atter and the mineral part of the soil justify e formulation of a general principle, as llows. Most of the humic and fulvic acid ntent (40%-50%) is linked to calcium, and ly 2%-3% to sesquioxides.

Humus formation in the Sivash soils has its vn special features. In the meadow solonetzes, e meadow vegetation apparently played its rt in the accumulation of organic matter, as n be seen from the increased content of humus compared with the meadow-steppe solonetzes. ie peptizing and hydrolyzing action of exchangele sodium has had the effect that the humus of e meadow solonetzes have become noticeably obile.

With the more intense draining of the territory, the replacement of former plant associations by more xerophytic ones, and the decrease of plant litter, the humus content in the meadow-steppe solonetzes declines. At the same time, its mobility rises; one-third of the humic acids are in the "free" state.

With the soil becoming more steppe-like in character as a result of grass replacing the *Camphorosma*-wormwood groups, and as the exchangeable sodium diminishes, a certain stabilization of the humus takes place and its content increases. This can be observed in the steppe dark-chestnut solonetzic soils; but the organic matter in these is still unstable, judging by the increased quantity of free humic acids. Only in the southern chernozem soils do the signs of humus mobility disappear.

The evolutionary transition from the meadow and meadow-steppe solonetzes through the steppe-dark-chestnut solonetzic soils to the southern chernozems is marked by a general accumulation of organic matter because of stabilization and accumulation of the humus and the gradually increasing structural complexity of the humic substances, i. e., their "aging." The content of humic acids bound to calcium gradually rises in the north-to-south direction, forming the following series for the soils referred to: 25.8%-30.3%-31.1%-33.3%. In the soils of the whole series, humic acids predominate over fulvic and the ratio of humic-acid carbon to fulvic-acid carbon is 1.5-1.6 in the solonetz soils and 2.2 in the southern chernozem. Such a ratio is normal for the southern chernozem, as the literature (2) confirms. For the solonetz soils, however, it is quite uncharacteristic.

The reason for this phenomenon lies in the geological history of the Sivash. In the opinion of a number of investigators, the climate in the late Quaternary period was moister. Owing to this, the fresh-water intake was massive and a network of rivers existed where the bays of the Sivash are today (2, 7, 16). It can be assumed that at that time flood-plain-delta conditions prevailed far and wide in the area and this led to the development of the sod process of soil formation. Traces of this process have been found everywhere in the soils of the Sivash, for example: the soil has been worked by earthworms, which do not exist there today (5); there is deeper humification of the solonetz profiles, a sharply faceted granular structure into which the prisms and nut-like structure of the solonetzic horizon disintegrate, and a predominance of humic acids (bound to calcium) over fulvic acids. Later, with the subsidence of the land and the formation of the Sivash, the process of salinization of the soils and their acquisition of solonetzic features began (3, 4).

The humus of the Sivash solonetz soils, unlike the solonetzes of other regions, and also those of the Kerch peninsula, therefore consists of more mature, condensed forms of organic matter, although it does contain an increased quantity of the mobile groups owing to the peptizing influence of exchangeable sodium. In this respect the Sivash solonetzes occupy an intermediate position between the classic solonetzes and steppe soils.

Let us examine the humus composition of a Kerch solonetz developed on Tertiary clays. At 3%, and sometimes more, its total humus content is higher than that of the Sivash solonetzes. Its decrease with depth is more gradual (see Fig. 1).

The content of humic acids amounts to only 17%, as against 28%-34% in the Sivash solonetzes. At the same time there is a steep rise in the content of fulvic acids, which clearly predominate over humic acids, as a result of which the ratio of humic-acid carbon to fulvic-acid carbon is less than unity, i. e., 0.7-0.8.

The increase in the content of fulvic acids in the solonetz soils fully conforms to established patterns: they are regarded by M. M. Kononova as the least condensed representatives of the group of humic acids, with a more simplified structure (12, 14).

The Kerch solonetzes also have an increased content of humins. Apparently the processes of adsorption of humic and fulvic acids by the minerals of the soil are more strongly marked in the solonetzes developed on Sarmatian clays, which are particularly rich in clay particles.

It is notable that the "free" humic acid fraction is present here in much smaller quantities than in the Sivash solonetzes; it amounts to 1.1% as against 6%-11%.

The predominant form of binding of the humi and fulvic acids in the humus of the solonetzes developed on Tertiary clays is with calcium. Humic substances bound to sesquioxides are present only in very small quantities. But compared with the Sivash solonetzes, the sum of the fractions bound to calcium is considerably less; i. e., 37% instead of 42%-49%. The reason for this lies in the special nature of the soil-forming parent materials. The Sarmatian clays are exceptionally poor in calcium carbonates (0.2-1%), whereas the yellow-brown loess-like clays are very rich in them (15%-20%). Hence, one of the reasons for the differences in the humus of the solonetzes of the Kerch peninsula and the Sivash is the dissimilar content of calcium carbonates in the soil-forming parent materials.

Thus the humus of the Kerch peninsula solonetzes developed on Tertiary clays is characterized by predominance of fulvic over humic acids, and also by a smaller content of organic substances bound to calcium, as a result of the low calcium carbonate content of the parent material.

The distribution of organic substances in the deep-plowed meadow-steppe solonetz of the Sivash, of which Profile 244 serves as control, is most singular. Deep plowing to a depth of 60-65 cm brings part of the carbonate horizon to the top; the humus horizon becomes mixed with the solonetz and carbonate horizons and moves lower down, to a depth of about 30-40 cm. For this reason, the upper part of the deep-plowed layer contains 1.21% humus, the value for the deeper level of 30-40 cm being 1.77%.

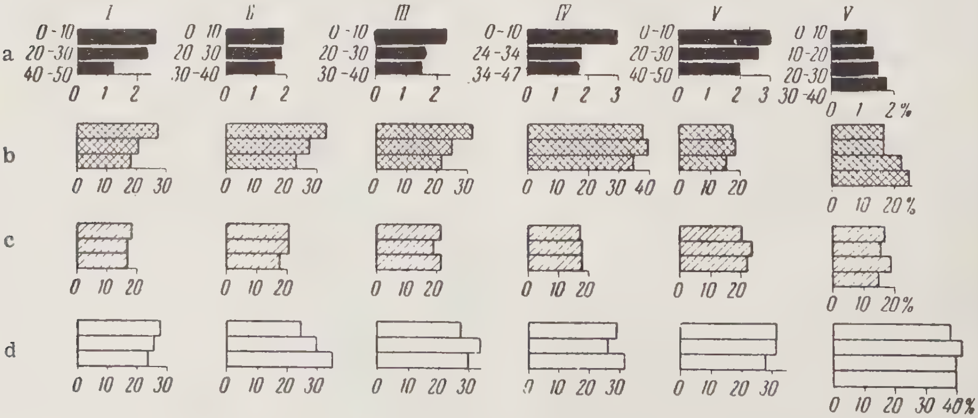

Fig. 1. - Composition of humus in solonetz and other soils of the Crimea

I - Meadow solonetz; II - Meadow-steppe solonetz; III - Dark chestnut solonetzic soil; IV - Southern slightly-humified chernozem; V - Steppe solonetz on Sarmatian clay; VI - Deeply plowed meadow-steppe solonetz: A - Humus; B - Humic acids of fractions I and II; C - Fulvic acids of fractions I and II; D - Humins.

The content of humic and fulvic acids changes n the soil profile according to the distribution f humus. In the upper part, the humic acid ontent is minimal — 12.8%; at a depth of 30-40 m it reaches its maximum of 22.5%. At the ame time the relative content of humins in the umus of the top layers rises steeply. The reaon is that much of the underlying carbonate orizon is concentrated here, and in the carbonte horizon humins characteristically predomnate over humic and fulvic acids.

The generally observed increase of humins n the humus of the lower soil horizons may be aused by the fact that most of the humic acids escending from above and those forming in situ re adsorbed by the minerals in the soil (26), hile in the upper horizons newly formed humic ubstances enter the soil faster than the mineral art can adsorb them. This would explain why he more mobile forms of humus predominate t the top.

A group ratio of humic substances in the pper plowed horizons in which the more tighty bound, passive forms predominate over the ctive, is less favorable from the point of iew of structure formation and soil fertility n general. It is therefore essential to inrease the fertility of newly deep-plowed soils. n the first years after deep plowing, manure nd mineral fertilizers must be applied which ontribute to the accumulation of humic subtances favorably affecting structure formation 15). Irrigation is also desirable: by increasng yields and ensuring the entry into the soil f large quantities of organic residues, it actiates microbiological processes and helps to ransform the organic material (5).

At a later stage, when the deep-plowed soil as undergone further "aging" and if the corect measures have been taken, humus will egin to accumulate in it, as A. M. Mozheyko oted (17), and the usual humus composition ill disappear.

Conclusions

1. The composition of humus in solonetz oils of the Crimean region is not uniform. In he humus of solonetzes developed on Tertiary lays in the Kerch peninsula, fulvic acids preominate over humic acids. In the solonetzes nd solonetzic soils of the Sivash developed on ellow-brown loess-like clays, on the other and, humic acids predominate over fulvic. 'his may be explained as an effect of a sod rocess preceding the solonetzation.

2. Solonetz soils of the Sivash are also istinguished by their increased content of free" humic acids, particularly the meadowteppe solonetzes.

3. In newly deep-plowed solonetz, the humus has an unusual composition because considerable large soil from the lower horizons is lifted to the surface. In the upper part of a thick plow layer, the humic acid content is lower, and there is a relative increase in the content of the less active forms of organic matter, namely the humins. To increase the fertility of newly deep-plowed solonetz soils, organic and mineral fertilizers should be applied and the soils should be irrigated.

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DETERMINATION OF PHOSPHORUS IN SOIL EXTRACTS BY THE ULTRAVIOLET SPECTROPHOTOMETRIC METHOD

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The analytical chemistry of phosphorus includes many different methods for determining this element, which is of vital importance for plants and animals. In practical agricultural chemistry, use is often made of Niessen's method for determining total phosphorous content (4) and the different modifications of Denigě's method for determining available phosphorus in soil (1). The first of these methods is tediously minute and extremely laborious; most important, moreover, is the fact that it is not precise enough, in that the composition of the yellow phosphomolybdic complex precipited in the course of analysis is not constant (4, 7). As for the various modifications of Deniğe's colorimetric method, which provides for the use of stannous chloride as a reducing agent, they are known to have many substantial shortcomings. For example, the color of solutions of the phosphomolybdic complex restored by stannous chlorides is unstable; the reproducibility of the results depends upon the duration of the separate analytical operations, the quantity of the reducing agent added and the purity of the stannous chloride; the soil extracts have to be given prolonged chemical treatment before the colorimetric process in order to eliminate substances which impede determination of the phosphorus, etc.

One of us has previously studied the conditions in which a blue phosphomolybdic complex is obtained with the reduction of yellow phosphomolybdic acid with hydrazine sulfate, ascorbic acid and other reagents. He has also evolved a method of determining microquantities of phosphorus by infrared spectrophotometry (8, 9). These researches resulted in the study and selection of the optimum physicochemical conditions for obtaining solutions of a blue phosphomolybdic complex for which the light-absorption properties remain stable over a long period of time. When optimum conditions for the reactions of complex-formation are present, the determination fo phosphorus cannot be impeded by silicon, organic acids, or the cations of many elements (except arsenic).

The spectrophotometric method referred to was used to determine available phosphorus in the soil (11). Use of the method in practical soil research has made it possible to improve the system for determining phosphorus in soil samples and to introduce production-like methods into all analytical operations.

Later on we studied the possibility of developing a simple and highly sensitive method of determining phosphorus in soil extracts and other solutions with ultraviolet (UV) spectrophotometry. The method is based on a property of solutions of the yellow phosphovanadomolybdic complex (PVMC) — the property of intense absorbtion of UV radiation. In the visible band of the spectrum this complex possesses a small molar coefficient of light absorption; it is therefore not sensitive and accurate enough. This is probably why Misson's method and its modifications (2-3, 6-7, 12-15), based on visual colorimetric determination of phosphorus according to the intensity of the yellow of PVMC solutions, have been used mainly for the analysis of metal ores, fertilizers and other materials containing comparatively large quantities of phosphorus. Mission's method is poorly suited to determining microgram quantities of phosphorus.

Our experiments have shown that the value of the molar coefficient of light absorption (ϵ) and also the wavelength ($\lambda,_{max}$) corresponding to the maximum absorption of the PVMC formed in the reaction, depend to a great extent on the conditions under which the complex-forming reaction takes place: concentration of H^+, of vanadomolybdic reagent (VMR), presence of extraneous ions, and other factors.

Our spectrophotometric research[1] enables us to state the following: the optimum concentration of H^+ for binding phosphorus in PVMC should be regarded as 1N for sulfuric or nitric acid; the molar ratio $P_2O_5:V_2O_5:MoO_3$ in solution must be compared to 1:36.4:1600 and, consequently, the ratio $(V_2O_5):(MoO_3)$ should be 1:44.

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[1] Measurements in the UV band were made with an SP-4 spectrophotometer ($\lambda_{max,}$ = 336 mμ). Source of radiation was an incandescent lamp.

Influences impeding the determination of PVMC by the UV spectrophotometry method may be exerted chiefly by silicon, ferric oxide, and humus substances. We had found earlier that silicon is bound most fully in the molybdenum complex at pH values of 1.5-3.0 (10). An increase of (H^+) to 1N prevents the formation of this complex. Silicon behaves in exactly the same way in the formation of the vanadomolybdic complex. When (H^+) = 0.1N, silicon with VMR forms a silico-vanado-molybdic complex (SVMC), the ϵ of which is 5400, and the λ_{max} = 351-352 mμ. On the other hand when (H^+) = 1N, silicon, within certain limits of concentration (0-1 mg SiO_2 in 50 ml of solution), is practically not bound in SVMC, and the solutions studied do not absorb in the UV band. Thus the presence of up to 1 mg of SiO_2 in 50 ml of the tested solution does not in practice impede the determination of phosphorus. But a further increase (of SiO_2) with precisely the same concentrations of reacting components brings about a perceptible change in the spectral properties of the solutions and leads to unsatisfactory results as regards phosphorus. The SiO_2 content in ordinary acid extracts from soils is such that, in the solution prepared for photometry, the SiO_2 concentration does not exceed 0.5 mg per 50 ml of solution. This permits us to ignore the impeding influence of SiO_2 when determining phosphorus in soil extracts by the UV spectrophotometry method proposed by us.

There are indications in the literature that the process of PVMC formation is practicable when (H^+) = 0.04-0.07 N (16). But this degree of acidity is quite unacceptable for the analysis of soil extracts, when one takes into account the impeding action of silicon, which is easily bound at low concentrations of H^+-ions in the UV-radiation absorbent SVMC.

Unlike silicon, ferric oxide, when present in a photometrically analyzed solution in quantities of 0.3-0.5 mg or more in 50 ml of solution, does impede determination of PVMC by the UV spectrophotometry method, since certain complexes of iron absorb UV radiation intensively. The spectral characteristics of nitric acid solutions of iron and its compounds with VMR, with and without phosphorus, are shown in Figure 1. The data shown that a solution of 5 mg Fe^{3+} in 5 ml of 1N nitric acid (Curve 1) absorbs considerably less in the band λ_{max} = 340 mμ than when VMR is present and phosphorus absent (Curve 2). The increase of the light absorption value (E) observed in the latter case testifies to the formation of ferric-vanadomolybdic complex (FVMC) which absorbs in the UV band.

The same figure shows the spectral characteristics of nitric acid solutions containing, respectively, 0.1 mg and 0-5 mg Fe^{3+} in 50 ml (Curves 3-7). It follows from these data that the increase for the photometrically analyzed nitric acid solutions as against FVMC is directly proportional to the concentration of ferric oxide in the solutions studied. The mean increase of E, when 0.1 mg Fe^{3+} is present, is 00.1.

We have determined the ferric oxide content in many different initial soil extracts and in corresponding solutions prepared for the photometry process. Determination of the iron in the solutions studied was done by the rhodanide method, using a PEC-M photo-

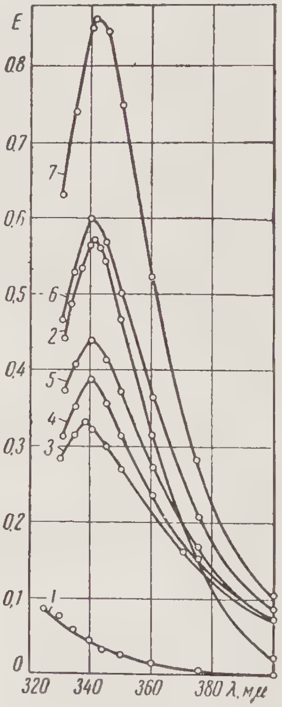


Fig. 1. - Spectral characteristics of nitric acid solutions of ferric oxide and its vanadomolybdic complex.

1 - 5 mg Fe^{3+} in 50 ml 1N HNO_3; control solution (CS) - 1 N HNO_3; 2 - 5 mg Fe^{3+} + VMR in 50 ml 1N HNO_3; CS - VMR in 1N HNO_3; 3-7 - 0.1 mg P_2O_5 VMR + 0, 0.5, 1.0, 2.5, and 5 mg Fe^{3+}, respectively, in 50 ml 1N HNO_3; CS - VMR in 1N HNO_3.

electric colorimeter.

The results show that, as regards iron content, soil extracts can be divided into two groups.

First Group. Extracts for photometry, containing up to 0.1 mg of ferric oxide per 50 ml of solution. These include:

a) 0.5N acetic acid extracts of various soil samples;

b) 0.5N hydrochloric and 1% citric acid extracts obtained in the extraction of soil samples from podzols, podzolized and certain other soils.

Second Group. Extracts for photometry, containing more than 0.1 mg of ferric oxide per 50 ml of solution. These include 0.5N hydrochloric and 1% citric acid extracts from soils rich in iron (chernozems, sod-gleyed, peat soils and others).

In UV spectrophotometric analysis of the soil extracts in our first group, one can ignore the interference of the residual iron they contain. In analyzing the second group of soil extracts, it is essential first to eliminate the interference of the iron. Our researches have shown that the impeding action of ferric oxide can be eliminated by reducing it to bivalence with sulphite, ascorbic acid (AA) and other reducing agents. Ferrous oxide and its possible combinations with VMR do not absorb in the UV band and cannot therefore impede determination of PVMC by the UV spectrophotometry method.

Figure 2 depicts the spectral characteristics of ferric oxide solutions, each containing 2.5 mg Fe^{3+} in 1N solfuric acid, with and without VMR.

The data show that the abscissa of the light-absorption maximum of an FVMC sulfuric acid solution corresponds to $\lambda = 340$ mμ, as it does for the nitric acid solutions of the same complex (Fig. 1), and thus does not depend upon the nature of the acid used for the preparation of the solutions studied. It is interesting to note that the $E\lambda_{max}$ of the sulfuric and nitric acid VMR solutions, each containing 2.5 mg Fe^{3+}, noticeably differ, being 0.910 and 0.280 respectively. This is probably indicative of the difference between the sulfate and nitrate of the ferric oxide in their own absorption in the UV band of the spectrum.

We note the intersection of Curves 1 and 2 where $\lambda_{max} = 336$ mμ (Fig. 2). At this point the E values for the solutions of iron sulfate and for the FVMC are practically identical. The interference of ferric oxide contained in photometrically analyzed sulfuric acid solutions can therefore also be eliminated by the optical comparison method (i. e., by means of photometric calculation of the value of the iron sulfate's own absorption on the basis of the total light-absorption value for both PVMC and FVMC).

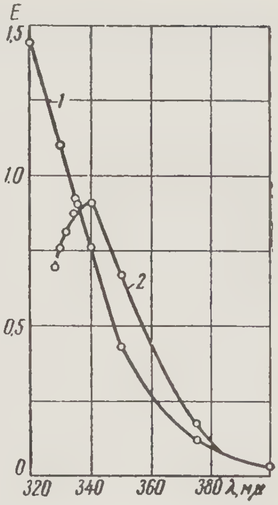
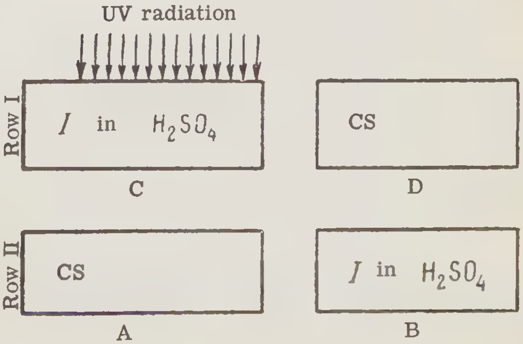


Fig. 2. - Spectral characteristic of sulfuric acid solutions of ferric oxide and its vanadaomolybdic complex.

1 - 2.5 mg Fe^{3+} + in 50 ml 1N H_2SO_4; CS - 1N H_2SO_4; 2 - 2.5 mg Fe^{3+} + VMR in 50 ml 1N H_2SO_4; CS - VMR in 1N H_2SO_4.

The technique of optical comparison is as follows: In the cells of an SP-4 spectrophotometer or PEC-56 photoelectric colorimeter fitted with a source and receiver of UV radiation (5) are placed respectively 4 or 6 cells of the same thickness filled with the solutions under study. When an SP-4 spectrophotometer is used, the cells are arranged in two rows, as follows:



where CS is the control solution containing all the reagents but not containing phosphorus. It is then established that the E value for the content of both pairs of cells is equal. When this has been done, cells A and B are emptied of liquid. Cell A is filled with the solution under study (SS), containing vanadate, molybdate, sulfuric acid and an aliquot of the extract being analyzed. Cell B is filled with a solution containing, in 50 ml of 1N sulfuric acid, exactly the same number of milliliters of soil extract as was used for the preparation of the SS. Then the photometry is carried out as usual.

In the photometry of nitric acid PMVC solutions, the optical comparison method cannot be used to eliminate the interference of significant quantities of ferric oxide (>0.1 mg per 50 ml of solution), for the absorption of iron nitrate and its vanadomolybdic complex in the UV band of the spectrum is not identical (Fig. 1, Curves 1 and 2).

We have studied the conditions of using ascorbic acid (AA) for reduction of the appreciable quantities of ferric oxide when VMR and phosphorus are present. The study established that addition of 3 ml of 2.5% AA solution into 50 ml of the sulfuric acid solution under study (not nitric acid — HNO_3 oxidizes AA), containing up to 2.5 mg Fe^{3+}, brings about complete reduction of the iron. One hour after addition of the reagent, the E value of the PVMC solutions, reduced by AA, becomes practically constant. When citric acid is present (in amounts of 0.04%) the E value of the reduced solutions becomes constant 1 hour and 40 minutes later. In a nitric acid environment and without AA, the E value becomes constant 30-40 minutes after addition of the reagents.

Ascorbic acid introduced into a PVMC solution reduces not only the iron but also the additives which enter the inner sphere of the complex. The spectral characteristics of reduced and non-reduced forms of PVMC, and also of phosphomolybdic complex (PMC) restored by AA, are shown in Figure 3.

The ϵ-values of PVMC and PMC, measured in the UV and nearest infrared bands of the spectrum, are shown in Table 1.

As we have already remarked, the determination of phosphorus in soil extracts by the UV spectrophotometry method can be interfered not only by silicon or ferric oxide, but also by colored humus substances which absorbed UV rays. The interference of the humates can be eliminated by the optical comparison method described previously.

In eliminating the interference of humates present in citric or hydrochloric acid extracts containing noticeable quantities of iron, after the instrument has been set at "null," a solution must be poured into cell B containing, in 50 ml of final volume, 10 ml 5N H_2SO_4, 3 ml 2.5% AA and a corresponding number of milliliters of the soil extract. The AA is introduced into the solution to be compared because it is necessary to reduce the ferric oxide (which is intensely absorptive in the UV) to the bivalent state. When residual quantities of Fe^{3+} are present, distilled water is poured into cells B and C instead of 1N H_2SO_4.

We have found that the presence in 50 ml of the solution under study of 100 mg of calcium chloride or sulfates of magnesium, potassium, aluminum or manganese does not interfere with determination of 0.1 mg P_2O_5. The UV spectrophotometry method can be used to study sulfuric, hydrochloric, acetic, citric and other acidic soil extracts, and also water and acid solutions of orthophosphoric acid and its salts.

Sample calibration scales for PVMC solutions taken by us with an SP-4 spectrophotometer and PEC-56 photoelectric colorimeter are given in Figure 4.

The data in Figure 4 show that PVMC solutions, within concentration limits of 0-0.2 mg P_2O_5 in 50 ml of photometrically analyzed solution, conform to Beers law. The sensitivity of determination amounts to 0.002 mg P_2O_5 in 50 ml of the solution under study.

Technique of Determination. Analysis of 0.5N acetic acid extracts of different groups of soils, 0.5N hydrochloric and 1% citric acid extracts of soil samples from the podzolic and podzolized group.

Into a 50-ml volumetric flask are poured 20 ml of VMR (the reagent is prepared thus: the following are poured in succession into a one-liter flask: 500 ml of a 5N solution of nitric acid, 100 ml of 0.3% solution of ammonium vanadate, and 200 ml of ammonium vanadate, and 200 ml of a 5% solution of ammonium heptamolybdate, and distilled water up to the mark) and 2, 5, 10 or other numbers of milliliters of the soil extract prepared according to the generally accepted method (2 ml citric, 5 ml hydrochloric or 10 ml acetic acid extract, etc.). The flask is filled to the mark with water, shaken, and, after 30 minutes, photometrically analyzed, the optical comparison method being used to eliminate the interference of humates. A solution containing 20 ml VMR in 50 ml of liquid serves as control solution. Photometry is carried out with an SP-4 spectrophotometer (λ_{max} = 336 mμ) or PEC-56 photoelectric colorimeter (λ_{max} = 365 mμ). The light-absorption of the PVMC solutions remains unchanged for five to six days. Using the measured results, the P_2O_5 content in 50 ml of photometric liquid is found on the calibration scale compiled beforehand, after which, by multiplying by the appropriate dilution factor,

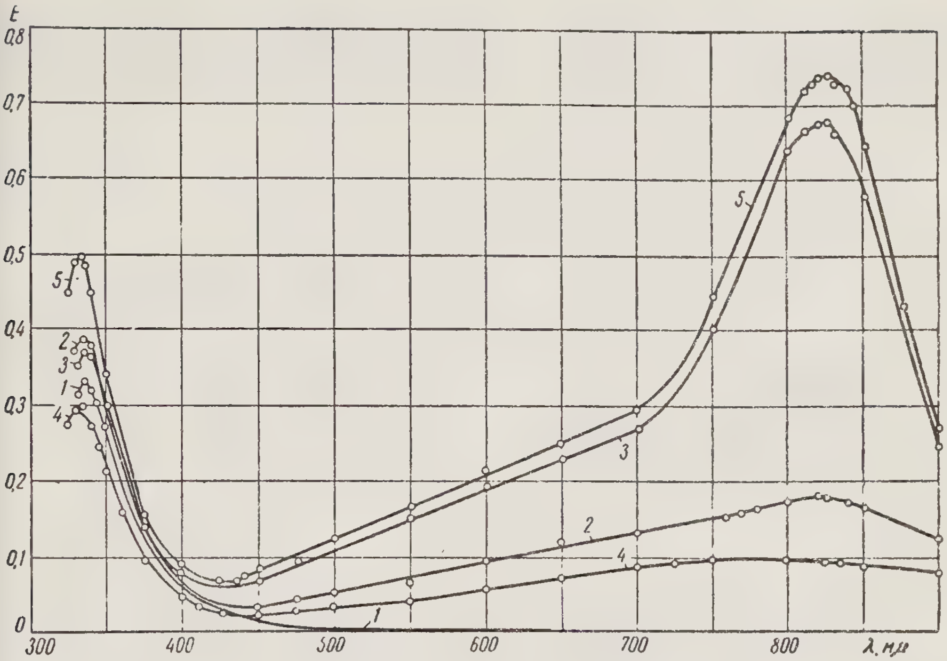


Fig. 3. - Spectral characteristics of PVMC and PMC.

1 - PVMC in 1 N HNO_3; 2-3 - PVMC in 1 N H_2SO_4, reduced by AA at 18° and 100°C, respectively; 4-5 - PMC in 1 N H_2SO_4, reduced by AA at 18° and 100°C, respectively.

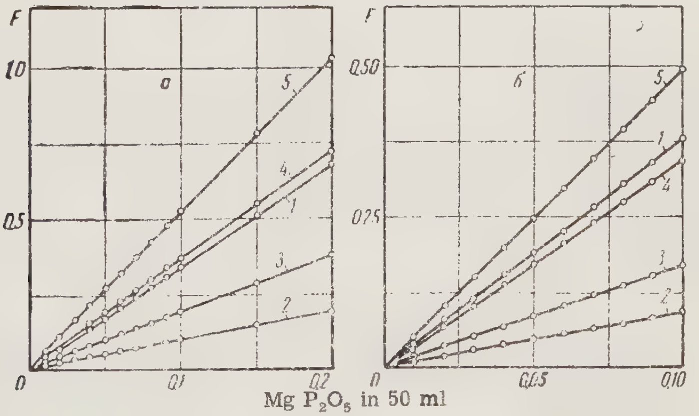


Fig. 4. - Calibrations for PVMC solutions.

a - In 1 N HNO_3; b - In 1 N H_2SO_4, AA present. 1 - Taken on SP-4 spectrophotometer with λ_{max} = 336 mμ and thickness of liquid in cell (d) equal to 1 cm; 2-5 - Taken on PEC-56 photoelectric colorimeter with λ_{max} = 365 mμ and d = 0.5, 1,2 m and 3 cm, respectively.

e content of P_2O_5 in mg per 100 g of soil is lculated.

Analysis of acetic, hydrochloric, sulphuric d citric acid and other soil extracts obtained in the extraction of different soil samples.

Into a 50 ml flask are poured 20 ml of VMR, which has been prepared as described previously, except that the 5N nitric acid is replaced by sulfuric acid of the same normality. Then 2, 5, 10 or another number of milliliters of the soil extract are added: distilled water is added to approximately 45 ml; the flask is shaken; and with a pipette 3 ml of a 2.5% newly prepared AA solution are added. The liquid level is brought up to the mark and the mixture left for one hou (1-1/2 to 2 hours in the case of analysis of citr

Table 1

Value of PVMC and PMC converted to 1 mole P_2O_5

Name of complex	Value of ϵ when λ_{max} is	
	336 м μ	825 м μ
PVMC	23 600	—
PVMC reduced by AA cold	27 200	12 700
PVMC reduced by AA boiling	26 400	48 000
PMC reduced by AA cold	20 200	7 100
PMC reduced by AA boiling	34 000	52 500

Table 2

Results of comparative determination of phosphorus content in 0.5 N acetic and hydrochloric acid soil extracts prepared by Cherikova-Shkonde's method, in mg P_2O_5 per 100 g of soil

Soil	UV spectrophotometry method and use of SP-4 equipment		Standard method and use of PEC-M equipment
	With AA	Without AA	
Acetic acid extracts			
Sod, slightly-podzolic	3.0	3.5	3.6
Sod, latent-podzolic	5.8	5.2	6.0
Sod, slightly-podzolic	10.5	10.0	10.4
Sod, gleyed	2.0	2.5	2.2
Sod, somewhat gleyed	1.5	2.5	2.2
Sod, gleyed	1.0	1.25	1.0
Grey-podzolized	9.5	8.5	9.0
Grey-podzolized	6.0	4.75	5.4
Sod, medium-podzolic	3.5	3.25	3.0
Sod, gleyed	2.0	2.25	2.8
Hydrochloric acid extracts			
Sod, latent-podzolic, somewhat gleyed	19.5	—	19.0
Sod, slightly-podzolic gleyed	14.0	—	12.5
Sod, medium-podzolic	8.0	—	8.0
Sod, slightly-podzolic	31.5	—	31.4
Sod, gleyed	9.0	—	8.0
Sod, somewhat gleyed	40.5	—	39.0
Light-grey podzolized	65.0	—	63.0
Peat of lowland bog	20.2	—	20.0
Meadow, thin thickness	15.5	—	13.6
Sod, medium-podzolic	—	4.0	4.2
Sod, slightly-podzolic	—	6.0	6.4
Sod, medium-podzolic	—	0.0	0.0
Sod, medium-podzolic	—	0.0	0.0
Chernozem, podz. slightly water-erod	—	19.5	20.4
Sod, medium podzolic	—	30.2	30.0
Dark-grey podzolized	—	32.2	34.9
Grey, podzolized	—	19.5	21.0

Table 3

Results of comparative determination of phosphorus in citric acid soil extracts prepared by the Arrhenius method, in mg P_2O_5 per 100 g of soil

Soil	UV spectrophotometry method with optical comparison (without AA) and use of equipment:		Standard method and use of PEC-M equipment
	SP-4	PEC-56	
Acid photometric solutions 1 N H_2SO_4			
Sod, slightly-podzolic, medium-gleyed	8.8	9.2	8.3
Sod, medium-gleyed	19.7	19.3	19.0
"	25.5	24.3	27.3
"	26.5	25.0	27.0
"	6.3	5.0	5.3
Acid photometric solutions 1 N HNO_3			
Grey-podzolized	6.7	6.3	6.2
"	24.3	25.3	27.0
Light-grey podzolized	12.0	13.5	12.9
Grey-podzolized, somewhat gleyed	8.0	9.5	9.4
Sod, slightly-podzolic	3.6	4.2	3.8
"	16.0	17.2	16.0
Sod, medium-podzolic	12.2	13.2	12.1
Grey, heavily-podzolized	10.8	10.0	10.9
Sod, latent-podzolic	21.3	21.3	21.9
"	—	15.2	15.0
"	—	14.0	16.0
	—	12.7	12.4

Table 4

Results of comparative determination of phosphorus in citric acid soil extracts prepared by Arrhenius method, in mg P_2O_5 per 100 g of soil

Soil	UV spectrophotometry method with AA and use of equipment		Standard method and use of PEC-M equipment
	SP-4	PEC-56	
Sod, latent-podzolic, somewhat gleyed	14.7	14.7	14.4
Sod, medium-gleyed	15.7	15.3	15.5
Sod, latent-podzolic, somewhat gleyed	6.7	6.3	7.7
Meadow, flood plain	11.0	10.0	11.7
Sod, medium-podzolic	4.0	4.0	4.7
Sod, slightly-podzolic, medium-gleyed	19.3	19.5	19.4
Sod, medium-podzolic, medium-gleyed	3.5	3.5	3.7
Sod, medium-podzolic, strongly-gleyed	10.0	9.0	10.1
Sod, medium-podzolic, gleyed	9.7	8.5	10.5
Grey-podzolized	34.0	32.0	30.5
"	8.75	8.50	9.6
"	18.50	19.75	20.0
Sod, slightly-podzolic	12.5	11.0	12.6

acid extracts). The control solution contains all the reagents except phosphorus. The photometry and calculation of P_2O_5 content per 100 g of soil are carried out as described previously. The PVMC solutions reduced by AA can be photometrically analyzed in two days.

We have made comparative tests using the proposed UV spectrophotometry method in determining the phosphorus in many samples of hydrochloric, acetic, and citric acid and other soil extracts. The standard method was the photometric method of determining phosphorus by the blue molybdenum complex using hydrazine sulfate (11). Measurements in the UV band of the spectrum were made with an SP-4 spectrophotometer (λ_{max} = 336 mμ) and partly with a PEC-56 photoelectric colorimeter (λ_{max} = 365 mμ). Photometry of solutions of the blue phosphomolybdic complex were carried out with a PEC-M photoelectric colorimeter using a red filter. Some results of the comparative tests are given in Tables 2, 3 and 4.

The results of the comparative tests of the method we propose, given in Tables 2, 3 and 4, allow us to recommend the UV spectrophotometry method of determining phosphorous in soil extracts and other solutions. The method is sufficiently accurate and sensitive; it is simple, reliable and convenient, and it can be used for the mass analysis of soil samples. Its use makes it possible to introduce a production-line system into analytical operations.

Our method of determining phosphorus in soil extracts by means of UV spectrophotometry has found successful practical application in the mass-scale soil investigations conducted by the staff of the Ukrainian Scientific Research Institute of Agriculture.

Conclusions

1. Conditions governing the formation of the phosphovanadomolybdic complex (PVMC) were studied.

2. Research was conducted on the interference of silica, ferric oxide, humates and other extraneous substances in determining PVMC by the ultraviolet (UV) spectrophotometry method. The content of ferric oxide in acid extracts from different soil samples was determined. Physicochemical means are proposed for eliminating the interference of extraneous substances in determining PVMC by the UV spectrophotometry method.

3. Absorption spectra of the PVMC and phosphomolybdic complex (PMC) measured were in the UV, visible, and near infrared (IFR) bands of the spectrum. The molar light-absorption coefficients of PVMC and PMC in the UV and IFR bands have been calculated.

4. A simple and convenient method of determining phosphorus in acid soil extracts (and also in solutions of orthophosphoric acid and it salts) by the UV spectrophotometry method is suggested. The method's sensitivity is 0.002 mg P_2O_5 per 50 ml of solution. The light-absorption values of the solutions studied remain practically unchanged over a long period of time. Examples of calibration scales are given for determining phosphorus by the UV spectrophotometry method using an SP-4 spectrophotometer (λ_{max} = 336 mμ) and PEC-56 photoelectric colorimeter (λ_{max}=365 mμ).

5. Comparative tests of the proposed metho were carried out on many soil samples. Their results enable the method to be recommended for wide-scale laboratory use.

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QUALITATIVE COMPOSITION OF AGGREGATES OF CERTAIN VOLGA-KAMA FOREST-STEPPE SOILS

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In recent years a number of works have been published on the need for further study of soil structure: mechanism of its formation (1, 2, 6, 8, 9, 10, 11), its productivity significance (1, 3, 13), methods of conservation and restoration structure. (4, 11, 13), and creation of synthetic soil conditions (7, 12). The investigators have shown that humus, adsorbed bases (Ca), and sesquioxides play the major role in structure formation. However, none of these factors has been studied in detail. Nor have the qualitative properties of aggregates, especially under different physico-geographic and soil conditions, received adequate attention. The latter circumstance led us to investigate the qualitative composition of aggregates of certain Volga-Kama forest-steppe soils.

We used for this purpose samples of the most widespread soils in this area: gray forest, cinnamon-brown gray, and leached chernozem. Aggregates measuring 3.0-1.0-0.25, and <0.25 mm in diameter were taken from three horizons in each of these soils by means of dry screening. Both the original soils and isolated fractions of different aggregates were examined. A determination was made of the humus according to Tyurin, mobile humic acids according to Pankova, mobile iron according to Kirsanov, total SiO_2, R_2O_3, and P_2O_5 by the usual method in the original soils, total adsorbed bases according to Kappen in Madanov and Voykin's modification, and the aggregate composition by Savvinov's method (wet sieving). Table 1 shows the physiocochemical composition of the original soils.

The data in Table 1 indicate that the samples have different physicochemical properties. For example, whereas the leached chernozem contains 8.09%-7.91% humus in the plowed layer, the cinnamon-brown gray and gray forest soils contain 3.71% and 3.29% humus, respectively. The sharpest decrease in humus in the profile occurs in the gray forest soil. The total of adsorbed bases also changes in accordance with the humus and mineral colloid (total R_2O_3) content of these soils and changes in the profile. A little mobile iron is in the upper horizon of the leached chernozem. The maximum quantity is in the upper horizon of the cinnamon-brown gray forest soil owing to the natur of its parent material. In this respect the gray forest soil occupies an intermediate position. The content of mobile iron increases with depth in all the soils. The behavior of mobile iron in the profiles of the soils investigated agrees with the data of one of the author of this article (5). Examination of the data by the amount of mobile humic acids shows that t latter is found — in absolute amounts and in percentages of the total humus content — mostly in the gray forest soil, then in the leached chernozem, and least of all in the cinnamon-brown gray soil. The amount of mobile humic acids in all the soils decreases with depth in the profile. The content of total SiO_2 and R_2O_3 and change in profiles confirm the genetic characteristics of these soils. An analysis of the figures shows that the gray forest soil was formerly sodpodzolic. It lost its purely podzolic horizon because of farming activity.

The soils in question are also characterize by different aggregate composition. It is evident from Table 1 that the maximum amount of water-stable aggregates >1 mm in diamete is found in the plowed layer of the cinnamon-brown gray soil, the smallest amount in the same horizon of the gray forest soil. First in content of this fraction in the lower part of the humus horizon is the leached chernozem, whereas in horizon B it is the cinnamon-gray soil that is first. The fraction of water-stabl aggregates >0.25 mm in diameter is distribut somewhat differently in these soils. The amount in the plowed layer decreases almost by half from the leached chernozem to the gray forest soil. This pattern is also observed in the lower part of the humu (cf. horizon A_1 and $B_1{}^1$) where it is even more pronounced. In illuvial horizon B the amount of the fraction of water-stable aggregates is maximal in the cinnamon-brown gray soil.

Table 1

Data on the physicochemical analysis of the original soils

Profile No.	Soil and location	Horizon	Depth, cm	Humus, %	Mobile humic acids as a % of the humus	Total of adsorbed bases, meq per 100 g	Mobile iron, mg per 100 g	Total			Aggregate analysis			
								SiO_2	R_2O_3	P_2O_5	Content of fractions as a % (diameter in mm)			
								in %			>3	>1	>0,25	<0,25
1	Leached chernozem, Stalin Kolkhoz, Buinskiy rayon	Ap	0—14	8.09	3.58	47.11	0.61	61.39	19.60	0.141	6.30	11.16	41.52	58.48
		Ap	14—24	7.91	3.79	46.52	1.95	61.91	19.38	0.138	0.92	5.78	41.66	58.34
		A_1	24—42	6.02	2.33	44.12	2.10	60.88	18.35	0.125	12.12	45.74	80.24	19.76
		B	81—102	1.18	None	Not det'd.	8.81	58.75	20.30	0.094	0.44	10.07	28.79	71.21
419	Cinnamon-brown gray forest, Voroshilov Kolkhoz, Upper Uslonskiy rayon	Ap	0—20	3.71	3.24	21.20	7.23	59.38	22.30	0.128	6.18	16.18	31.36	68.64
		B_1	22—32	1.96	None	16.80	8.95	62.21	20.25	0.110	2.00	29.98	67.04	32.96
		B	40—50	0.93	"	19.55	14.45	58.64	25.10	0.098	3.36	41.20	48.48	51.52
2	Gray forest, Michurin Kolkhoz, Arskiy rayon	A_p	0—20	3.29	12.73	17.54	4.41	72.29	14.25	0.104	0.22	1.58	24.00	86.00
		B_1	20—25	0.96	10.42	9.81	3.62	74.91	13.01	0.091	0.10	0.70	9.96	90.04
		B	30—40	0.50	4.00	11.23	15.06	70.81	15.61	0.068	0.28	2.86	23.62	76.38

The greatest amount of water-stable aggregates >0.25 mm in diameter in the leached chernozem is due to the fact that it is richer in humus and adsorbed bases than the other soils investigated. Moreover, our data show convincingly that the cinnamon-brown gray forest soil is also characterized by a rather high percentage of this fraction of water-stable aggregates, although it contains half as much humus and adsorbed bases as the chernozem. The explanation of this phenomenon is to be found, we believe, in the fact that the cinnamon-brown gray forest soil is much richer in mobile iron and total sesquioxides than the leached chernozem. The water stability of the structural aggregates is markedly less in the gray forest soil, which is much poorer in adsorbed bases and humus than the chernozem and at the same time is much poorer in mobile iron and sum of total sesquioxides than the cinnamon-brown gray soil (in the first two horizons). This decrease shows up most vividly in the lowest part of the humus horizon. Thus, the content of water-stable aggregates in the plowed layer of the gray soil is 1-1/2 to 2 times smaller than in the same horizons of the soils considered previously, but it is 7 to 8 times smaller in horizon B_1[1]. The significantly lower water stability of the structure of the gray forest soil as compared with that of the cinnamon-brown gray soil, despite their almost identical content of humus and adsorbed bases, is occasioned by the difference in iron content.

Let us now examine the chemical composition of different aggregates from the three soils discussed. The analysis data are presented in Table 2.

The data on humus content in different fractions of the aggregates shows that in all cases it drops from the finer aggregates (<0.25 mm in diameter) to the coarser (3 to 1 mm in diameter). The difference in humus content in aggregates of various diameters is greatest in all the horizons of the cinnamon-brown gray soil and least in aggregates from the gray forest soil; the chernozem in this respect occupies an intermediate position. Our findings on the distribution of humus in different aggregates conflict with Khan's data on the same subject (11). Khan says that "as the size of the aggregates decreases, the humus content steadily decreases." We do not have enough data at present to explain this discrepancy. The reason may lie in the local characteristics of the soils involved. However, it is worth noting that our department has available factual material obtained through the use of more "precise" methods of research on other soils and by other analysis confirming our findings.

Turning to the fraction of mobile humic acids in different aggregates and expressed as a percentage of the total humus content, we have observed the following pattern. The maximum content of humic acids is found in aggregates from the humus horizon of the gray fores soil; the second largest amount is in aggregate from the cinnamon-brown gray soil; the smalle amount is in aggregates from the chernozem. The content of mobile humic acids decreases in aggregates from the lower parts of the humu horizons of all soils while for horizon B this fraction is retained only in aggregates of the gray forest soil. We must stress that the aggregates <0.25 mm in diameter are richest in fractions of mobile humic acids, whereas aggregates 3 to 1 mm in diameter contain the least, i. e, the fraction of mobile humic acids in the aggregates varies directly with their humus content. This relationship can be followed in the aggregates taken from all three soils under investigation. The amount of mobile iron in different diameter aggregates also depends on the humus: it decreases from the finer aggregates to the coarser. The aggregates taken from the cinnamon-brown gray soi are first in absolute content of mobile iron, those from gray forest soil second, and those from leached chernozem last.

We conclude with an examination of the data on the total composition of the different aggregates shown in Table 2. An analysis of the values shows that the content of sesquioxides i the aggregates regularly decreases as they decrease in size. The aggregates from the cinn mon-brown gray soil are first in content of sesquioxides while those from the gray forest soil are last in this respect. A comparison of the data on content of total R_2O_3 and mobile iron in different diameter aggregates shows that the amount of the latter varies directly with the content of the former. Total phospho acid in different diameter aggregates varies d rectly with the content of humuc and sesquioxides, i. e, it decreases as the diameter of th aggregates decreases. It is interesting to not that the SiO_2 content of the aggregates likewise varies directly with the content of sesquioxide The simultaneous increase in total SiO_2 and R_2O_3 justifies the assumption that silicic acid increases in these aggregates at the expense of its colloidal or amorphous form.

Table 3 presents the results of determining the particle-size analysis of different aggregates taken from the chernozem. It is evident that there is a definite pattern to the changes in the physical clay and clay fractions in the different diameter aggregates. In the 3.0-1.0 mm diameter aggregates the content of the physical clay fraction is smaller than in the 1.0-0.25 mm diameter aggregates. There is deviation only in horizon A_1 where the amount of physical clay in the coarser aggregates is higher than in the finer ones (we were unable to verify the resultant deviation owing to the insufficiency of material). The change in cla fraction in the different diameter aggregates i less pronounced, but there is a tendency for i

Table 2

Qualitative composition of different-sized aggregates

Soil	Horizon	Depth, cm	Diameter of aggregates, mm	Humus %	Mobile humic acids as a % of the humus	Mobile iron, mg per 100g	Total SiO_2 in %	Total R_2O_3 in %	Total P_2O_5 in %
Leached chernozem, Buinskiy rayon	A_p	0—14	<0.25	8.01	3.62	1.28	68.30	20.4	0.141
	A_p	0—14	1—0.25	7.78	3.46	1.20	63.18	20.0	0.139
	A_p	0—14	3—1	7.51	3.20	0.72	61.01	19.3	0.122
	A_p	14—24	<0.25	7.95	3.25	2.06	58.31	18.8	0.130
	A_p	14—24	1—0.25	7.83	3.08	1.96	56.29	17.1	0.122
	A_p	14—24	3—1	7.69	2.86	1.20	56.02	16.7	0.119
	A_1	24—42	<0—25	6.38	1.87	3.01	60.30	20.1	0.116
	A_1	24—42	1—0.25	6.12	1.64	2.46	59.00	18.9	0.114
	A_1	24—42	3—1	5.77	1.20	1.95	56.20	18.5	0.107
	B_1	81—102	<0—25	1.75	None	8.90	59.00	21.4	0.092
	B_1	81—102	1—0.25	1.09	"	6.11	57.90	20.3	0.091
	B_1	81—102	3—1	0.96	"	5.48	56.80	19.9	0.083
Cinnamon-gray forest, Upper Uslonskiy rayon	A_p	0—20	<0.25	3.71	4.05	7.45	60.50	23.3	0.129
	A_p	0—20	1—0.25	3.29	3.64	7.06	59.50	22.4	0.123
	A_p	0—20	3—1	3.09	3.22	6.72	57.10	21.1	0.120
	B_1^1	22—32	<0.25	1.96	None	9.14	61.90	22.8	0.109
	B_1^1	22—32	1—0.25	1.54	"	8.70	59.70	22.1	0.102
	B_1^1	22—32	3—1	1.24	"	8.28	58.20	20.8	0.099
	B	30—40	<0.25	1.03	"	15.13	57.50	26.3	0.098
	B	30—40	1—0.25	0.73	"	14.45	54.40	25.5	0.096
	B	30—40	3—1	0.64	"	14.00	53.80	24.4	0.090
Gray forest, Arskiy rayon	A_p	0—20	<0.25	3.27	12.73	4.40	73.11	15.9	0.095
	A_p	0—20	1—0.25	3.13	13.22	4.00	72.00	15.1	0.094
	A_p	0—20	3—1	3.11	12.60	3.10	70.10	14.0	0.093
	B_1^1	20—25	<0.25	1.09	10.91	3.80	75.20	13.9	0.089
	B_1^1	20—25	1—0.25	0.99	10.10	3.50	74.80	13.6	0.088
	B_1^1	20—25	3—1	0.95	8.42	3.00	72.40	12.7	0.086
	B	30—40	<0.25	0.55	5.45	15.20	72.00	22.37	0.070
	B	30—40	1—0.25	0.53	3.77	15.00	70.90	20.49	0.068
	B	30—40	3—1	0.46	3.48	14.30	70.20	17.59	0.066

Table 3

Particle-size analysis of aggregates

Soil	Horizon	Depth, cm	Diameter of aggregates, cm	Fractions, mm >0.25	0.25—0.05	0.05—0.01	<0.01	0.01—0.005	0.005—0.001	<0.001
Leached chernozem	A_p	0—14	3—1	0.30	5.60	30.50	63.60	11.10	13.20	39.30
	A_p	0—14	1—0.25	0.44	8.36	25.90	65.30	13.00	11.50	40.80
	A_p	14—24	3—1	0.14	6.16	30.90	62.80	9.30	13.15	40.35
	A_p	14—24	1—0.25	0.40	6.20	28.25	65.15	[illegible]	14.60	41.00
	A_1	24—42	3—1	0.20	6.30	29.30	64.20	11.20	13.00	40.00
	A_1	24—42	1—0.25	0.48	7.32	28.80	63.40	11.20	11.95	40.25

o increase in the finer aggregates. Thus, the esults of determining the particle-size analysis of aggregates agree with the determinations of their total composition. The finer aggregates show an increase in content of the physical clay and clay fractions accompanied by an increase in total sesquioxides in aggregates of this diameter.

Conclusions

1. Aggregates of different diameter (3.0-1.0; 1.0-0.25, and <0.25) have a different qualitative composition.

2. Aggregates diameters <0.25 mm contain more humus, mobile humic acids, and total SiO_2, R_2O_3, and P_2O_5; they are richer in mobile iron.

3. Larger diameter aggregates (3.0-1.0 mm); on the other hand, are poor in humus, fractions of mobile humic acids, and total SiO_2, R_2O_3; and P_2O_5; they contain less mobile iron.

4. Aggregates 1.0-0.25 mm in diameter occupy an intermediate position.

5. The content of physical clay and clay fractions decreases in the finer aggregates.

6. This pattern in the qualitative composition of various sizes of aggregates is found in all the soils examined, both from the upper and lower horizons of the profiles.

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RESULTS OF USING GAMMA RADIATION TO MEASURE CHANGES N SOIL MOISTURE CONTENTS IN THE PAKHTA-ARAL SOVKHOZ

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The Research Institute for Hydrometeorologcal Instrument Construction was the first in he Soviet Union to devise a method and apparaus for measuring soil moisture by means of gamma rays (1). The method was tested in 956 by the Soil Melioration Laboratory of the All-Union Research Institute of Hydroengineerng and Melioration on the peat soils of the Meshcherskaya lowland (3) and was used in 957 to measure soil moisture under agriculturl production conditions on one of the major otton-growing sovkhozes in Central Asia — he Pakhta-Aral. The results of the latter exeriment constitute the subject of our commuication.

Observations of soil moisture were conductd for over three months embracing the entire rrigation season. At the same time parallel determinations of soil moisture content were made by the weight method.

It is a well known fact that the gammascopic method of determining soil moisture is based n the absorption of gamma rays by the soil which, when the mass is unchanged, varies with its water content and changes exponentialy. One can evaluate changes in moisture from hanges over a given period of time in the inensity of the gamma rays passing through a particular layer of soil.

The method of horizontal radioscopy was used on the Pakhta-Aral Sovkhoz. The source f gamma radiation was cobalt-60 with an activity of about six milligram-equivalents of radim. An STS-6 counter in an aluminum case nd IVP-64 field radiometer were used to regster the gamma rays. The soil was radiocoped to a depth of one meter by 10 cm layers. Three holes were dug 40 cm apart. To prevent hem from being damaged by interrow cultivaion, they were reinforced with pipes and placed ear the cotton plants. The gamma-ray source n a lead container-collimator was moved along he middle hole and the radiation measured at he outer holes in turn. The results of the measurements at these two holes constituted a replication of the experiment. Figure 1 is a diagram of the way the soil moisture was measured by the gammascopic method.

Control measurements by the weight method were made in a triple replication in the same layers and for the same periods of time. Holes for removing the samples were dug near the regular holes for radioscoping the soil in an approximately 10 m^2 area.

The experiment was performed on medium clay loam light sierozems of average salinity. There were three irrigations by overhead sprinklers during the growing period at the rates of 450, 700, and 600 m^3/ha. In addition, the cotton was supplied with moisture by ground water found initially at a depth of 2.2 m and at the end of season at a depth of 3.2 m. Changes in the moisture contents under these conditions are shown in Figure 2 where the different shading indicates the areas of replications made by the weight and gamma-ray methods. Concordant data on depth of soil wetting and drying of the root zone were obtained for all the horizons except for the surface. Peaks of increased moisture from irrigation were traced to 50 cm; further down, in the 50 to 100 cm layer, the effect of irrigation was scarcely perceptible. Moisture contents in this layer gradually decreased in accordance with consumption by the cotton.

Processing of the materials by statistical methods revealed a good correlation between data of the weight and gammascopic determinations. The correlation coefficient was about +0.90. We used the generalized method of analysis (2,4) to appraise the convergence of the data obtained by the different methods. There were about 30 determinations for each layer. The error of mean weight determinations was 9.6 m^3/ha per 10 cm layer or 0.65% soil weight. This amounted to 2.5%-5.0% of the measurable moisture contents.

As a criterion for determining the inclusion of gammascopic determinations in the variation

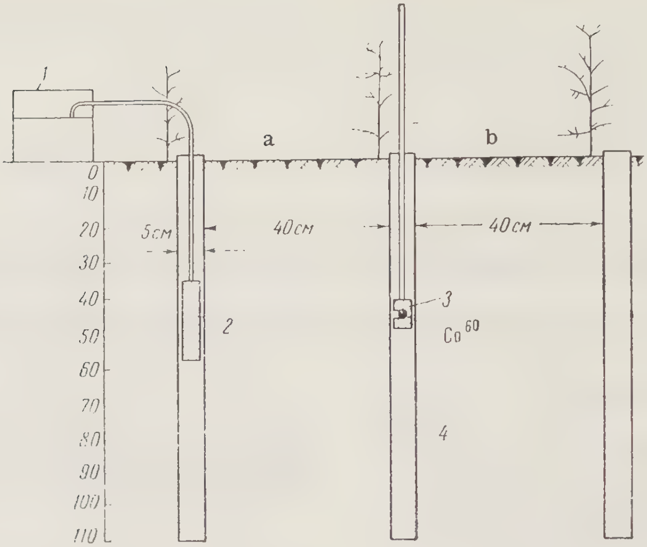

Fig. 1. - Diagram of hole arrangement for radioscopy of the soil by γ - rays.

A - first; B - second replication; 1 - measuring device; 2 - counter; 3 - lead container; 4 - pipe in hole.

series of weight determinations we used the ratio of the difference in means to their error

$$(t = \frac{M_1 - M_2}{m_\Delta}).$$

According to Styudent's tables, with a probability of 95% and the aforementioned number of observations the difference in means should not be more than double their error. For the 10-20, 30-40, and 70-80 cm layers this condition was violated in only four out of thirty cases, i.e., the overwhelming majority of the data obtained gammascopically agreed with the weight determinations.

However, for the 0-10 cm layer the convergence of data noted for the underlying horizons did not occur (Fig. 3). The moisture content determined gammascopically greatly exceeded the results of the weight determinations by 150 to 200 m^3/ha. The substantial excess of the difference in means over their error (five- to tenfold) suggests that the resultant data belong to different variation series.

The source of this discrepancy is the change in conditions of scattering the gamma rays in the surface layer which is adjacent to the air. However, preliminary experiments carried out in connection with this work show convincingly that compaction of this layer from irrigation was as significant as increased scattering of the rays. That is why the method of horizontal radioscopy is still unable to ensure satisfactory results in determining moisture contents in the surface layer of soil. Vertical radioscopy ma well largely solve the problem. In any case th search must continue for methods of determining moisture in this layer.

Throughout the period of observations, whic were made in the hot climate of Central Asia under growing conditions, the IVP-64 measure the moisture continuously. Nevertheless, observations of the control preparation cobalt-60 which were made all through this period, showed the need of introducing considerable corrections not only because of disintegration of the radioactive cobalt, but also because of decreased voltage of the electric battery. The corrections were so substantial that without them the results could not have been compared at all. Figure 4 shows that the difference toward the end of the season amounted to 30 to 40 m^3 per 10 cm layer.

The need of these corrections greatly complicates both direct measurements and subsequent calculations and is one of the major sources of error in the process. Obviously connected with this is the fact that the cases o noncorrespondence between the weight and gan mascopic determinations were noted mostly at the end of the experiment during the period pr ceding the change of batteries (the first half of August). Hence, devices to measure gamma radiation must be improved by providing for uniformity of voltage.

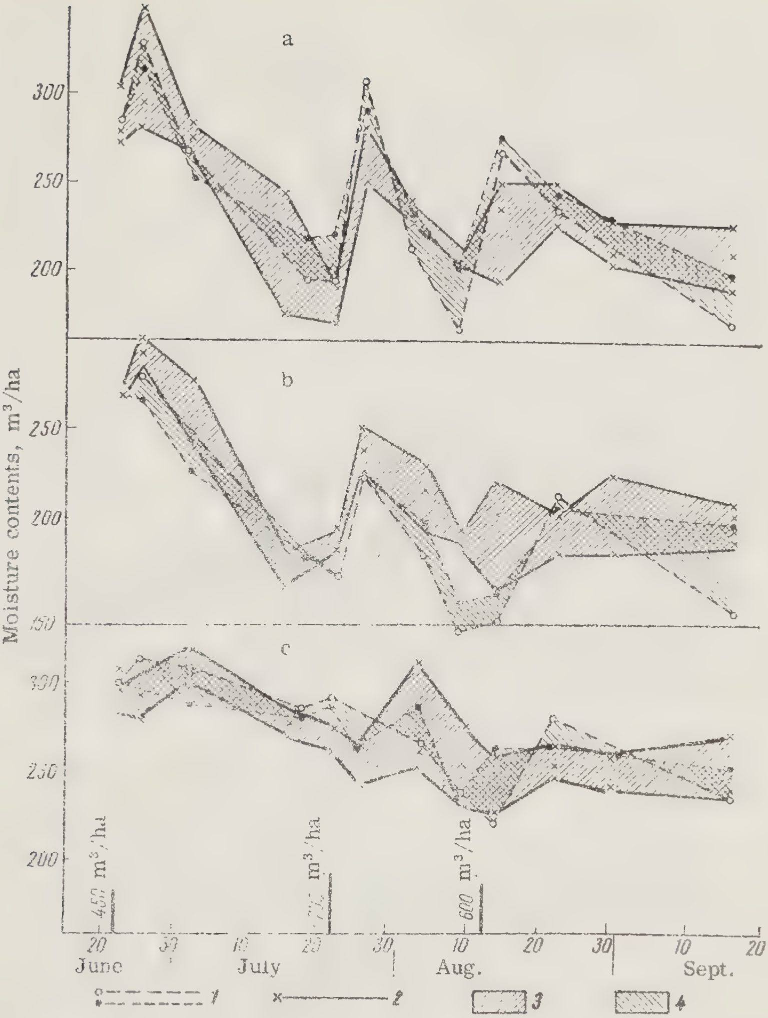

Fig. 2. - Changes in soil moisture contents with irrigated cotton on the Pakhta-Aral Sovkhoz as shown by the data of weight determinations and radioscopy with γ - rays.

A - 10-20 cm layer; B - 30-40 cm layer; C - 70-80 cm layer; 1 - method of γ - radiation; 2 - weight method. Zones of replicative determinations; 3 - weight method; 4 - γ - radiation method.

ne advantage of gammascopy is the possibi-
of obtaining the data more rapidly than by
ht determinations. The need of drying the
ples, which usually takes 8 to 10 hours,
s up the results until the next day and long-
On the other hand, gammascopy eliminates
need of drying the samples and makes it
ible to obtain the data immediately in the
. However, the actual amount of time re-
ed for gammascopic determinations is still
iderable, although less (approximately
2 times) than for weight determinations.
method has great potentialities for increas-
he speed of measurements by doing away
with all kinds of corrections, use of nomograms for purposes of calculation, mechanizing the shifting of the counter and cobalt along the holes, decreasing the reading time, etc.

The experiment in using gammascopy on the Pakhta-Aral Sovkhoz to determine soil moisture has been shown to be promising for irrigated fields. It may be cautiously used even now, but to obtain firm and reliable results both the design of the apparatus and the method itself must be improved.

Received September 13, 1958

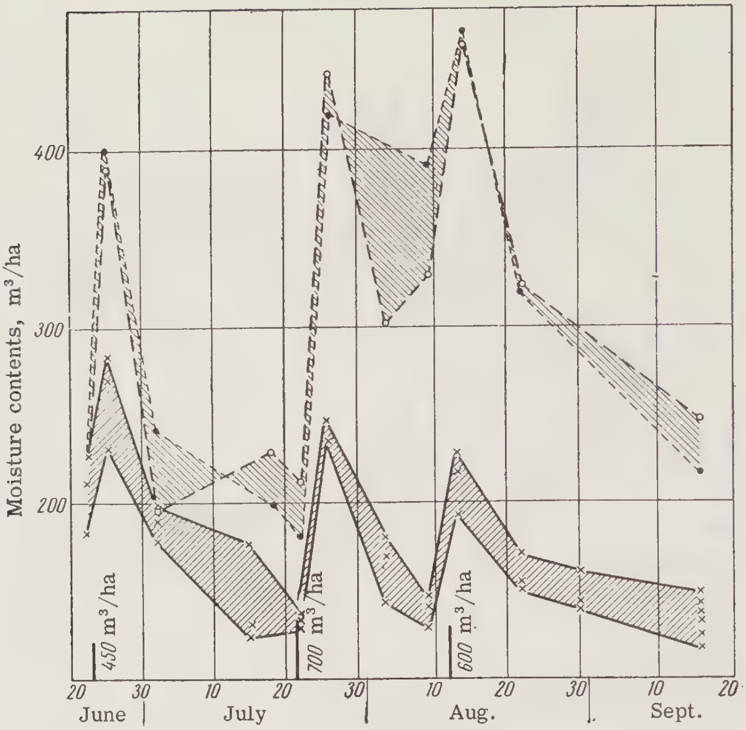

Fig. 3. - Moisture in the 0-10 cm layer determined by the weight method and by γ - radiation. Symbols are given in Figure 2.

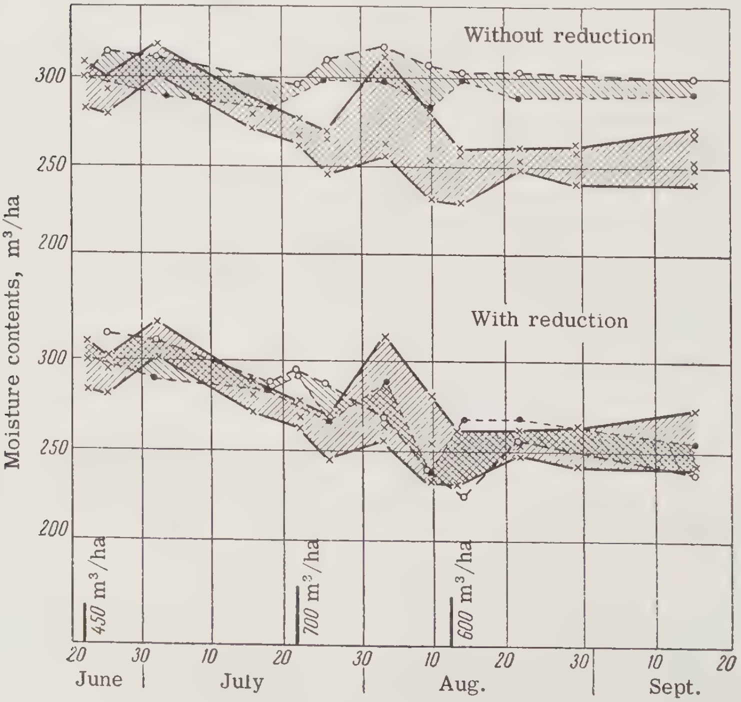

Fig. 4. - Effect of radioactive disintegration of Co^{60} and exhaustion of an electric battery on the results of measuring moisture contents in the soil. Symbols are given in Figure 2.

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PRINCIPLES FOR INTERPRETING AERIAL PHOTOGRAPHS OF ERODED FOREST-STEPPE SOILS

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The postwar decade has been characterized by large-scale aerial photography in the Soviet Union. Aerial surveys are mostly used to study and map the soil. Foreign research on the interpretation of aerial photography of eroded soils includes the works of Stübner (2) and Scogings and Frankel (3). Stübner shows that the indications of erosion — from slight sheet erosion to strong stream washouts — can be easily traced from aerial photographs. A comparative analysis of the materials and maps has shown that aerial surveys are superior to ground cartographic surveys for detailed studies of topography and erosion (2). Scogings and Frankel note the advisability of making periodic aerial surveys for a study of accelerated erosion in a region under investigation (3). The use of aerial methods for studying and mapping eroded soils has been scarcely discussed in Soviet literature.

This paper is based on soil cartographic materials obtained by aerial photography in the forest-steppe zone of Ryazan Oblast'. The territory forms part of the Oka-Don province of the forest steppe. The soil is characterized by widespread gray forest soils, podzolized and leached chernozems. Boulder and clay loams constitute the chief soil-forming parent material.

The land in the region is almost completely (about 85%) plowed. No more than 5%-6% is under forest. Meadow vegetation is found only along the ravines and flood plains.

The land in question has the well developed river and gully-ravine network associated with river valleys. The Most'ya, Para, and Pozhva Rivers have the largest and most developed valleys. The substantial number of gulleys and ravines near the valleys imparts a rugged, undulating character to the outlying parts of the interfluves. That is why these areas contain the greatest amount of rill and sheet erosion. The central parts of the interfluves are mostly flat areas as yet untouched by rill erosion.

Asymmetry is characteristic of the interfluves. The slopes coming down on the left banks of the rivers are gentle and consist ma ly of diluvial clay loam while the slopes of th interfluves on the right banks are steep. Th result is that the moraine on the steep slope is often eroded with glacio-fluvial sands app ing on the surface and frequently susceptible deflation. The main mass of growing gullies belongs to the steep slopes on the right bank of the rivers.

Photomaps clearly reflect both the indivic forms of the microrelief and the various elements of the mesorelief — gullies, ravines, steep slopes, etc. This is highly important soil purposes because it helps to determine character and degree of erosion prevalent in region being studied.

The interpretation of soil photomaps requ a special technique. The main problems are discover and delineate the genetic varieties the soil while determining and analyzing the soil contours marked on the maps. Office w must be combined with field study.

The soil of eroded areas can be identified either directly from the characterization of soil surface on photomaps or indirectly from the characterization of the vegetation (natura or cultivated). Both methods are used for tl forest-steppe zone. In direct interpretation main effect on the different soil characterist on maps will be exerted by the humus conter texture, degree of podzolization and erosion In indirect interpretation the degree of erosi and nature of vegetative cover are of major portance.

Specifically, soil identification is based p marily on the elements (direct and indirect) that are normally used in interpreting photomaps. At first, identification was a matter guesswork. Later, as aerial surveying advanced and came into use for the national ec omy, a number of elements — direct and ind rect — were worked out. The direct elemen clude the size, shape, tone, and shade of the ject; the indirect elements include the posi- on of the object with respect to the surround- gs, nature of its interrelation and interde- endence with other features of the landscape, c. This classification and the names of the terpretative elements suggested fully accord ith topographic, archeological, forest, and me other special kinds of interpretation. ney are largely adapted to soil interpretation. ne soil as an object of aerial photography pos- sses certain characteristics. For example, e soil contours may vary greatly in size and form. That is why these characteristics are t always important factors in identification. ade as a direct element is likewise not too lpful. At times it may even conceal the char- teristics of individual soil contours.

Nevertheless, there are several indirect ele- ents that are of great value in identifying soils, g., the pattern of characteristic soil surface photomaps, nature of the interrelation of the il, relief, vegetation, etc.

The character of the soil is closely associ- ed with the relief. Hence, identification, par- cularly in eroded areas, must be made with e help of instruments. Devices and paired ereoscopic photographs must be used both in e office and in the field. Appropriate equip- ent (stereoscope, stereometer, etc.) and ired photographs enable the soil scientist to tain a stereoscopic representation of the lo- l topography as well as to improve somewhat e readability of maps and ease of identification the soil.

When interpreting photomaps, it is highly portant to take into account the condition of e local objects at the time of exposure. For ample, cultivated plots usually show up more rkly than noncultivated plots. The shade of e individual soil contours and vegetation de- nds on the degree of soil moisture. The con- tions under which the photos were taken and bsequently developed may likewise have an fect. The phototone (degree of darkening of e emulsion) of natural objects changes mark- ly in the process. Thus, in interpreting a otomap it is not advisable to be guided by a ngle element, e.g., shade. A photographic pression of the soil can be analyzed with aximum accuracy only when all the elements e taken into account. Let us consider some the major elements.

Shade of picture. The tonal distinction be- een adjacent soil contours (between areas not fected by water or wind erosion) is exception- y important. Interpretation will be difficult impossible if the shade of an eroded area nds into the general background of the locali- Thus, the reproduction on photomaps of undary optical contrast of the image (different ades of image) is a primary requirement for ease in discerning objects. Actually, if the surface brightness of one soil contour does not differ from that of another contour, the boundary between them will naturally be invisible on photomaps. The FM photometer registered the spectral reflecting power of light-gray strongly podzolized forest soil, light-gray strongly podzolized eroded forest soil, and gray forest soil with signs of alluvium (Table 1 and Fig. 1). It turned out that the soils in question possess different reflections. Consequently, these soils of equal lightness reflect a different amount of light from the surface and show up on maps in a different shade. It is evident from Figure 1 that the light-gray eroded forest soil has the greatest brightness coefficients. These soils are represented on photomaps by a bright-light shade. Low reflecting power is found in the gray forest soil with the signs of alluvium so that it is represented by a dark-gray shade. The curve of spectral reflecting power of the light-gray strongly podzolized forest soil occupies an intermediate position and is represented by a light-gray shade.

Different soils are differentiated on black and white maps by a gray tonal scale. For all practical purposes the eye can distinguish about seven shades: white, bright-light, light, light gray, gray, dark gray, and dark. In those cases where the ground is not covered with vegetation, the color of the soil exerts the major influence on the shade of the picture. The color of the soil, particularly that of the top layer, is due chiefly to its chemical and mineralogical composition. It is created by a combination of black, red, and white colors. Accordingly, podzolized and leached chernozems are shown in the darkest shade owing to their substantial content of organic matter. Gray and dark-gray forest soils podzolized in varying degrees and containing less humus than chernozems are shown in gray shades of differing intensity. Light-gray strongly podzolized forest soils have the lightest shade. This is due not only to their insignificant amount of humus content, but also to the fact that they are more podzolized. Soil moisture and texture also strongly affect the shade by which the soil contours are characterized. The more moisture in the soil and the looser the surface, the darker the shade on the photomaps. Sandy and sandy loam soils show up in a lighter shade than do the clay loams. Areas of strongly eroded forest-steppe soils contain less humus, moisture, and clay particles than do noneroded areas. That is why these areas regularly show up in a bright-light shade (Figs. 2 and 3). Slightly and moderately eroded areas of gray forest soils are light gray (Fig. 2).

When the ground is covered with vegetation, the shade is used to identify the soil. The fundamental influence is exerted by the phenological condition and structure of the herbage (nature of the projective covering of the soil).

Table 1

Data on the spectral reflecting power of different soils

Soil	Depth, cm	M light filters						
		72	66	57	53	50	47	43
Light-gray forest, strongly podzolized	0—10	50	35	27	20	16	14	17
Light-gray forest, strongly podzolized, eroded	"	58	43	34	29	27	24	27
Gray forest with signs of alluvium	"	24	15	13	10	7	6	8

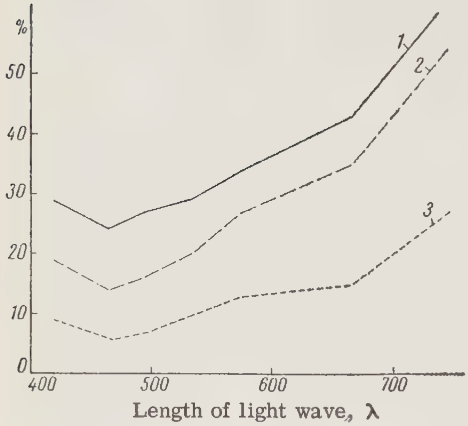

Fig. 1. - Curves of spectral reflecting power of soils.

1 - light-gray forest, strongly podzolized, eroded soil; 2 - light-gray, strongly podzolized; 3 - gray forest with signs of alluvium.

Moist areas with luxuriant grass appear in the darkest shade. On eroded areas both cultivated and noncultivated vegetation is frequently rather sparse. Sometimes the cultivated plants do not completely hide the eroded soil. In identifying eroded soils one must also be aware that steep slopes along ravines quite often are worthless eroded land covered with natural vegetation. On photomaps they show up in a light-gray or gray shade.

Pattern of picture. The picture pattern is another element used in interpreting photomaps. By pattern is meant the general nature of the picture of a given soil contour produced by the form, size, and different shades of the separate areas combined. This element is more persistent and reliable than shade for purposes of interpretation. For example, the picture of slightly and moderately eroded soils is mottle (Fig. 2). This pattern is due to the fact that the areas of microelevations are more eroded than the neighboring microdepressions. Thus, the former appear light, the latter light gray. On the other hand, a uniform pattern of bright-light shade is typical of strongly eroded soils. They are also characterized by the presence o ravines and gullies, which can be "read" with comparative ease on the photomaps (Figs. 2 and 4).

Size and form of soil contours. These do not have the clear definition of topographic, hydrographic, archeological, and other terrain features. Soil contours differ greatly in form and size. That is why these two items are onl of secondary importance in identification of soils. This applies completely to areas susceptible to sheet erosion.

Sometimes, however, the size and form of the contours are very well defined. Thus, furrows and gullies can be easily traced on maps. Gullies show up as narrow, serrated forms. They appear in a bright-light shade as a resul of erosion and denudation of the soil-forming parent material. One can also ascertain the stage of gully formation from photomaps. Th first stage — washout or channel — show up in the form of distinct linear projections (Fig. 4, 2). The second stage — hanging gullies — is characterized by a distinctly serrated form; small lateral furrows appear. At this stage th gully with its mouth still does not reach the bo tom of the ravine, forming a drop. This phenomenon can easily be traced on photomaps fr the gray shade distinguishing the light mouth o the gully from the dark-gray bottom of the ravine (Fig. 4, 3). At the third stage of gully development — formation of a "profile equilibrium" — the gully loses its hanging mouth and reaches the bottom of the ravine or level of th river. Deepening causes the banks to crumbl with resultant widening of the gully. This sta

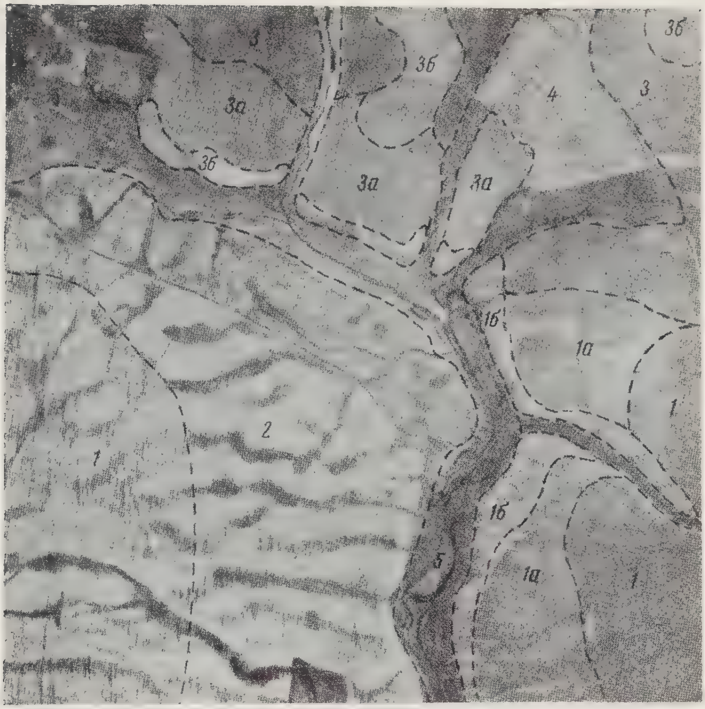

Fig. 2. - Aerial photograph of a forest-steppe area. Ryazan Oblast'.

1 - dark-gray forest soils: a - moderately eroded; b - strongly eroded; 2 - podzolized chernozem; 3 - gray forest soils: a - moderately eroded, b - strongly eroded; 4 - sod dark-colored; 5 - alluvial sod; 6 - gleyed sod and gleyed soils.

an be identified from its substantial size and ranching form. The gully with its mouth in a ight shade rests on the bottom of the ravine. 'he material carried out from the gully is deosited near it along the bottom of the ravine nd represented on photomaps by spots or treaks in a light shade. The slopes look like teep vertical cliffs so that their contours are harply outlined (Fig. 4, 4). The fourth stage - tapering out — is characterized by considerble width and less steep slopes. The slopes nd tops of the gully are overgrown with vegetaon. This stage is identified on photomaps priarily from the image of the vegetation. The ottom of the gully, covered by gully alluvium, s shown by a thin bright-light streak.

Gradually, gullies turn into ravines. On hotomaps ravines have an elongated and somehat sinuous form. The bottom and slopes are overed with vegetation. The contours of the pper portions are generally represented on aps by a uniformly gray shade, which matches e less hydrophilic vegetation and the developent of gleyed sod soils. The middle and lower ortions of the ravines show up dark gray from the denser hydrophilic vegetation and prevalence of gleyed sod soils. On spectrozonal photomaps ravines can be distinguished very easily by the cinnamon-brown or greenish-brown color. The picture pattern reveals the presence of isolated small dark spots extending along the thalwegs which correspond to small isolated areas with open water. Sometimes the pattern has a thin, sinuous dark line representing the stream in the ravine.

Nature of the topographic forms. The character of the soil is closely related to the various topographic forms, especially those of the microrelief. Hence, in soil research it is highly important to study the relief of the land being mapped. With aerial photography this task can be considerably lightened because most of the time the relief is directly shown on the photographs. A knowledge of the interrelations of soil and relief makes it possible to utilize stereoscopic images of topographic forms as a means of identifying the soil. For example, convex slopes, ridges, terraces, and other prominent forms are most susceptible to wind erosion. On photomaps (Fig. 3) the portions of

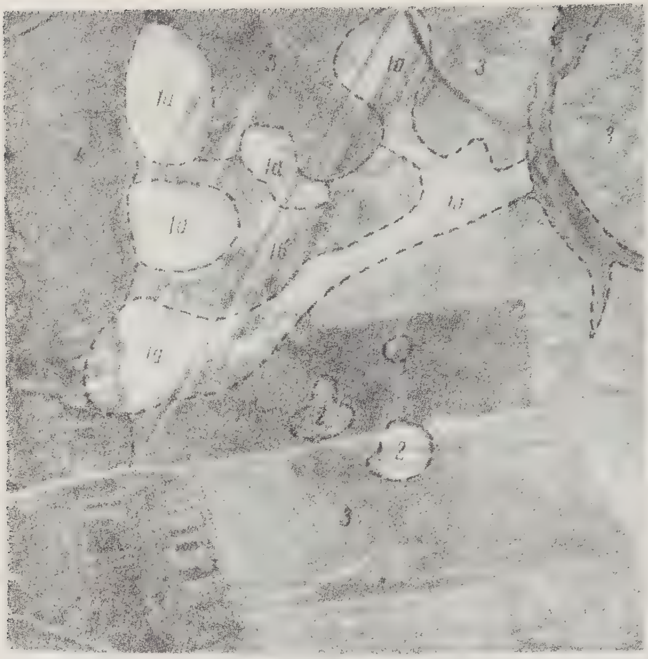

Fig. 3. - Aerial photograph of a forest-steppe area. Ryazan Oblast'.

1 - light-gray forest soils; a - sandy, sandy loam undergoing deflation, b - medium clay loam; 2 - light-gray gley and gleyed soils; 3 - gray forest soils; 4 - dark-gray forest soils; 5 - sod dark-colored.

soil undergoing deflation are readily detected from the character of the relief, shade, and picture pattern.

Sandy and clay soils can be distinguished by the nature of the relief shown on photomaps. For example, the sandy slopes of the original river banks and ravines are usually gentle and appear in a light shade. Cliffs fringing the slopes are characteristic of clay and clay loam soils.

We must also keep in mind the fact that aerial photography furnishes completely objective material capable of serving as a basis for the compilation of soil maps. This material can be systematically obtained over any number of years for regions studied for soil erosion purposes. Utilization of such material and stereoscopic measuring devices helps us not only to determine the length, width, and depth of gullies on photomaps, but also to study the growth of gullies and amount of land lost as a result. This feature of aerial photography is particularly important for research on the dynamics of soil erosion processes.

In addition, aerial photography makes it possible to observe the relationship of gully form on a plane to the form of the slope on which rill erosion develops. For example, linear, rhomboidal, club-shaped, beaded, and other forms of gullies are easily traced on photomaps. Systematic aerial survey materials are of value in distinguishing the types of branching of the gully-ravine network and in establishing the relation of the branching to the form of water-basin area. Accordingly, photomaps that cover a wide area are helpful in making visual appraisals of the various types of erosive dissection of the Soviet Union.

Interrelation of soil and vegetation. In aerial photography of soils covered with vegetation, soil identification is based chiefly on a study of the vegetation and determination of its relation to the soil. Three common variants are to be distinguished here: a) natural grass, b) cultivated, and c) forest.

Indirect identification of the soil from the direct pictures of natural grass vegetation is extremely important in the arid steppe and semidesert zones of the Soviet Union. Natural vegetation has survived in the forest-steppe zone mainly along the ravines and flood plains. It is also found on the steep slopes of valleys and ravines that are either worthless or eroded

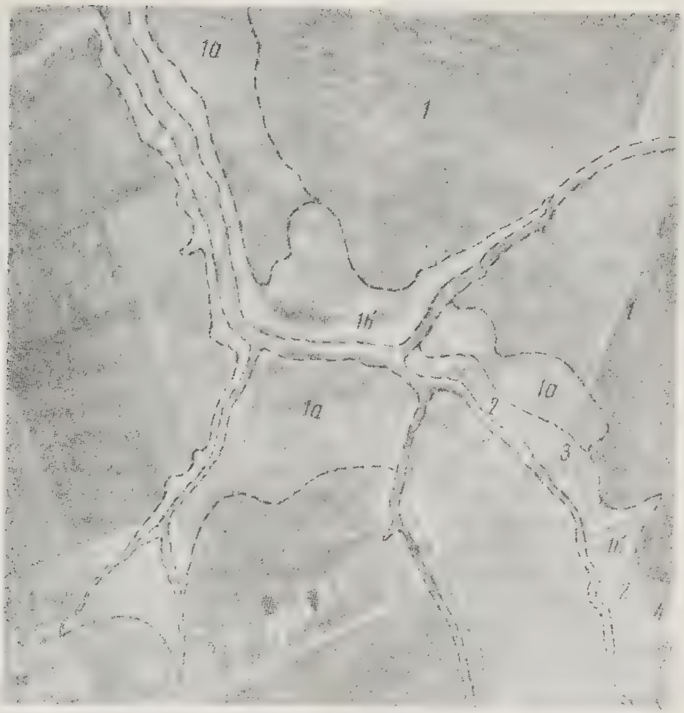

Fig. 4. - Aerial photograph of a forest-steppe area. Ryazan Oblast'.

1 - podzolized chernozem: a - slightly to moderately eroded; b - strongly eroded; 2 - washouts; 3 - hanging gullies; 4 - gully in the stage of producing a "profile equilibrium."

ands or unsuited for cultivation.

Soil identification from the direct image of
ultivated crops on photomaps is of maximum
mportance on farm lands. These are chiefly
he agricultural districts of the sod-podzolic,
orest-steppe, and steppe zones of the Soviet
Jnion. The pattern and shade of image of the
rops is influenced mostly by the nature of the
rops, their phenological condition, and pro-
ective covering of the surface. Cultivated
rops tend to level out the differences in image
f the soil on photomaps, as can very easily be
een on plowed plots, except in the case of
roded, stony, or very moist soils. We com-
ared two areas photographed at different
mes. Figure 5 a, shows one of the areas in
he forest-steppe zone with direct picture of
he soil. Figure 5 b, shows the same area, but
ith direct picture of the crop — rye in the
tage of waxy ripeness. A comparison of the
wo photographs reveals a sandy ridge exposed
deflation on both.

Soil identification from the picture of forest
egetation has still not been worked out. Here
nd abroad there is little material on the subject.
Troll (4) has only the following brief note. In heavily forested districts (where the ground is not visible) the different rocks, soils and ground water produce unusually sharp contrasts in the vegetation. That is why the vegetation in these cases may be used as a basis for forest as well as soil-geological interpretation.

The use of color spectrozonal aerial photographs holds out new and broader potentialities for identifying soils undergoing erosion. A comparative analysis of the black-white color spectrozonal photographs has shown the following. The best results as far as ease of identification is concerned was obtained with SN-2 film taken with a yellow ZhS-18 light filter and printed on color spectrozonal paper. In this connection the most interesting photos are those which in the course of processing show the soil in nearly natural colors. Use of the yellow ZhS-18 light filter with SN-2 film has somewhat enlarged the spectral zone acting on the panchromatic layer of this two-layer film and thereby helped in interpreting certain details of the soil. Specifically, spectrozonal photographs are more detailed and sharper than

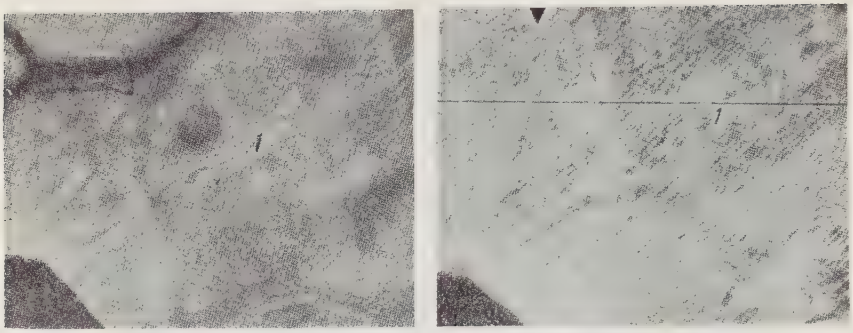

Fig. 5. - Aerial photographs of the same forest-steppe area. Ryazan Oblast'.

a - plowed plot; b - planted to rye. 1 - sandy ridge.

panchromatic photographs in showing soil changes in relation to humus content, moisture, and nature of the erosion. On black and white aerial photographs the differences in degree of erosion and humus content can be detected from changes in the scale of grays, whereas on spectrozonal photographs they can be detected from changes in the greens and yellows. On panchromatic photographs the contours of ravines with gleyed sod soil blend with the shade of the contours of gray forest soils. On spectrozonal photographs the boundaries of ravines can be clearly distinguished by the brown color, etc. Consequently, spectrozonal aerial photographs are more easily interpreted for the purposes of soil cartography than the universally popular panchromatic photographs.

Conclusions

1. Aerial photography makes it possible to locate and map regions undergoing rill and sheet erosion as well as to determine the extent and form of the erosion processes.

2. Identification of eroded soils requires the use of a variety of elements. Moreover, shade, pattern, and interrelation with the topography are of basic importance in identifying soils undergoing sheet erosion.

3. Aerial photographs not only reveal the forms of rill erosion and the various stages of gully formation, but also serve as objective material for describing the various types of erosive dissection of the Soviet Union and for studying the dynamics of the processes involved.

4. Utilization of color spectral aerial photographs holds out new and broader potentialities for identifying eroded soils.

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DYNAMICS OF SHRINKAGE AND EXPANSION OF INDIVIDUAL LAYERS IN A VERTICAL PROFILE, AND CHANGES OF SOIL POROSITY DURING CULTIVATION

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Various processes take place in plowed soil eading to an increase or decrease in its thickess. The result of these processes may be ither a uniform expansion or shrinkage of all ndividual layers of the vertical profile of a ield, or a simultaneous expansion of some ayers and compression of others. Theoreticaly it is possible that in some cases the thickness f a field remains unchanged during a certain period, while some of its layers are expanding and the others shrinking to the same extent.

An accurate accounting must be made of the hrinkage and expansion of the plow layer in rder to make correct deecisions regarding various practical questions, such as, for nstance, how deep to plow a fallow field, how deep to plow a field in spring before planting, ow deep to till between rows and between clumps f plants, etc. In addition, for accurate determination of the dynamics of the various processes hat occur in the soil, it is very important to measure systematically the qualitative changes hat affect the thickness of the individual layers.

What actually happens is this. Samples are aken from the individual layers to study the dynamics of various properties and processes, uch as changes in moisture, in the content of itrates, etc. Augers of various designs are ften used for this. But since the auger is lunged to a given depth, say 10 cm no allownce is made for changes in the thickness of a articular soil layer between two consecutive amplings. If a layer has been compressed in he meanwhile, then the second sample will nclude material that was below the bit the irst time. And if there is a vertical expansion, he second sample will not cover the whole layer tudied in the first sample.

Factors which cause shrinkage of the soil rofile and its individual layers are the following: a) settling under its own weight; b) he mechanical effect of rain drops; c) microial destruction of substances which cement he soil particles into aggregates; d) rapid jection of trapped air by water, leading to the destruction of soil aggregates; e) capillary pressure, through which the water menisci pull the soil particles together when the soil dries; f) dehydration with shrinkage; g) thawing of frozen soil; and h) compaction by machines, implements, fertilizer spreaders, harvest wagons, etc.

A number of factors associated with increase in soil volume are also known: a) swelling as moisture increases before the full physical optimum condition is reached (at about 60-70% of the full capillary moisture); b) evolution of gases from the breakdown of organic matter; c) freezing of moisture in the soil; d) formation of soil aggregates through the action of plant roots and organic fertilizers; 3) burrowing animals; and f) loosening of soil by cultivation, etc.

The "rod" method. In 1947 we proposed the use of a "rod method" (6, 7) for direct field determination of the expansion and shrinkage of the individual layers of the soil profile. This method consists of the following: 1-cm square wooden rods are driven into a field to a given depth (for instance, bottom level of the furrow at 30, 20, or 10 cm deep). The rods are arranged in parallel rows. Each row may contain as many as 20 rods, so that twenty replications may be obtained. Each row differs from the others by the rod length and the depth of their penetration. We used rods of the following sizes: 43 cm long, driven to furrow depth in areas plowed 30 cm deep; 2) 33 cm long, driven either 30 cm deep, where the plowing was deep, or to furrow depth, where the plowing was to the normal depth; 3) 23 cm long, driven to a depth of exactly 20 cm; and 4) 13 cm long, driven 10 cm deep.

The extent of shrinkage or expansion of each individual layer of the field during a given period can be calculated by periodically measuring the protruding portions of the rods. The rods are removed if work (cultivating, sowing, etc.) has to be done in the area and then replaced in the same order.

Calculation procedure for the "rod method." The following method of calculation is used to determine the expansion and shrinkage of individual layers of the soil profile during a given period. First of all, changes in the thickness of the upper layer are determined. (For instance, of the layer from 0-10 cm). If the length of the protruding portion of a rod has decreased, it means that the volume of soil has increased. In other words, during the given period the upper layer has expanded. By the same token, an increase in the length of the protruding portion of a rod means a decrease in the volume of soil, i. e., a shrinkage of that layer. After determining the volume changes in the upper layer, we proceed to calculate the amount of expansion or shrinkage in the next, second from the top, soil layer. To do this, it is necessary to subtract the new depth reading of the upper rod from that of the second rod, etc.

A study of the shrinkage and expansion of individual layers of the vertical profile of a field by the "rod method" was conducted by us on a medium clay loam leached chernozem at the field experiment station of the Voronezh Agricultural Institute over a period of seven years (1947-1948, 1951-1952 and 1955-1957).[1]

During this period investigations were conducted on the following different fields with two crop rotations: black fallow, autumn plowed land in winter-and spring-grain and a potato field. This paper summarizes the results of the investigations pertaining to the black fallow and fields in winter crops.

Investigations on black fallow. Even the initial observations showed that a change in the thickness of individual layers occurred in plowed fields that had been left uncultivated for some time. This change was caused primarily by the following two factors: settling under its own weight, and swelling after absorbing rain. For instance, in 1947, during the thirty days (May 29-June 28) between the first and second cultivations, the upper layer of the black fallow gradually subsided from 10 cm to 9.6 cm. Also compressed by 0.2 cm was the layer at the bottom of the furrow (20-23.9 cm deep). During the same period, after a rain early in June, the moisture penetrated deeper than 10 cm, causing an expansion of the 10-20 cm layer by 3 mm.

A uniform shrinkage of all layers under study was observed, during a period between cultivations, in a different black fallow field which had been plowed 20-22 cm deep in the fall of 1947. This was caused by a prolonged lack of precipitation in 1948 (from June 1 until August 15). The original thickness of the plow layer was re-established as the upper layer was loosened after each tilling (8-10 cm deep) with the shovel cultivator. But by the time of the next cultivation, a new shrinkage of all soil layers under study took place (Table 1).

In 1951, however, a swelling primarily of the upper 10-cm layer of a black fallow field, during the preceding fall, was observed in almost all tests during the period between the second and the third cultivations (July 11-Augus 10) (Table 1). This was due to a considerable amount of precipitation during this period: 22.8 mm of rain between July 18 and 26, 42.6 mm between July 26 August 2, 33.9 mm between Augus 4 and 10.

In the two previously-mentioned instances, the changes in the thickness of the layer of the bottom of the furrow (below 20 cm) were relatively small. However, when there are considerable moisture fluctuations at this depth, the changes in the thickness of this soil layer are quite noticeable. The results of an investigation, conducted in the fall of 1952 on a field where autumn plowing to a depth of 20 cm was done on September 2, are an example, of this (Table 1). A shrinkage of the lower layer (20-25.5 cm) caused by the natural compression of loose soil, was observed here during the first week after plowing. But the following week (September 8-15), during which 35.8 mm of rain fell, moisture reached this depth and caused an expansion of the lower soil layer by 0.8 cm. The following thirty days witnessed a gradual shrinkage of this layer. A new expansion ocurred after rains at the end of October.

A quantitative knowledge of the shrinkage and expansion processes in the different layers of a field assures the correct choice of equipment and depth for cultivation of black fallow, autumn-plowed land; and row-crop land. For instance, when only the upper layer (0-10 cm) is subject to shrinkage, a shallow loosening of the field may be sufficient. On the other hand, when the shrinkage of the lower layer is considerable, it may be advisabl to use a chisel cultivator.

Investigations on fields in winter wheat. Shrinkage and expansion of individual parts of the soil profile also take place in fields under crops, and the opposite processes may be occurring in two adjacent layers. The following factors play a very important role in determining the quantitative expression of these processes: the soil consistence, the depth of penetration of precipitation into the soil, and the impact of raindrops.

The sharp differences in the thickness of

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[1] The following persons participated in this work: Student N.G. Karpov (1948), Student N.A. Minakov (1951-1952), Post-graduate Student L.I. Khramtsov (1955-1957).

Table 1

Shrinkage and expansion of individual parts of the plow layer (medium clay-loam leached chernozem)

On Black Fallow										On autumn plowland after winter-wheat				
1948	Layers				1951	Layers				1952	Layers			
	I	II	III	whole thickness		I	II	III	whole thickness		I	II	III	whole thickness
1. VI	10.0	10.0	4.0	24.0	10.VII	10.0	10.0	3.3	23.3	1. IX	10.0	10.0	5.5	25.5
16. VI	9.5	9.8	3.9	23.2	18.VII	9.7	10.1	3.6	33.4	8. IX	9.9	10.0	5.1	25.0
29. VI	9.1	9.7	3.8	22.6	26.VII	10.1	10.0	3.5	23.6	15. IX	10.0	9.8	5.9	25.7
5. VII[a]	10.0	10.0	4.0	24.0	3.VIII	10.4	9.8	3.6	23.8	23. IX	9.9	9.8	5.4	25.1
20. VII	9.4	9.9	3.8	23.1	10.VIII	10.7	10.2	3.5	24.4	30. IX	10.1	9.9	5.2	25.2
26. VII[a]	10.0	10.0	4.0	24.0						14. X	10.2	10.0	5.1	25.3
11. VIII	9.3	9.9	3.8	23.0						28. X	10.4	9.9	5.5	25.8

[a] Rearrangement of pods took place.

ividual layers in the fall of 1951 and 1952 ler winter wheat sowed on black fallow are y significant. For both experiments the ck fallow was plowed 30 cm deep with three nmer cultivations to a depth of 6-8 cm. The t of these cultivations took place seven days or to the winter sowing. In addition, in May each year, manure at a rate of 20 metric tons hectare was plowed into the soil to a depth 20 cm.

In the fall of 1951, during September and tober, the field under the winter wheat wed a uniform, and slight (0.2-0.3 cm) inkage of all soil layers under observation 10, 10-20, 20-30, 30-31.5 cm). This resulted m the small amount of precipitation (42.8) during the entire period (light rains). The ns did not contribute to any noticeable expann of the soil but merely prevented its further inkage. In addition, the soil was compressed a certain degree by the wheels of tractors planting machines during the sowing.

The nature of changes in the thickness of inidual layers on another field under a winter p in the fall of 1952 was completely different. e precipitation during September and October hat year amounted to 143.7 mm, while some he end of September was in the form of heavy wers. This gave a particular pattern to the ume changes in individual layers of the verti- profile of the field. In the second half of tember the upper layer (0-10 cm) shrank iceably (from 10 to 9.4 cm), but by the end October it expanded to its original size. e next soil layer (10-20 cm) underwent a cm expansion of the profile by the end of tember, when the moisture reached this th. The volume increased remained until end of October. A gradual expansion was observed in the layer at furrow depth, 30-34.5 cm from the surface of the field. This expansion was considerable (1.0 cm, i. e., 22.2%) by the end of October, when moisture from the rains had penetrated the entire thickness of the plow layer. The swelling of these two soil layers (10-20 cm and 34.5-35.5 cm) led to a shrinkage of the layer at 20-30 cm. By the end of October it had shrunk to 9.1 cm, i. e., by 9%. The results of these investigations are given in Table 2.

The foregoing differences in the expansion and shrinkage of individual layers of the profile in the fall of 1951 and in the fall of 1952 undoubtedly affected the crops during the winter seasons. The 1951-1952 winter wheat wintered well. During the winter of 1952-1953, however, there was considerable thinning of the winter crop, aggravated by the winter thaws and the formation of ice crusts in the small depressions. It is quite possible that the strong opposed fluctuations in the volume of adjacent soil layers (expansion of some and shrinkage of others) during the fall of 1952 could have ruptured some of the roots of the winter wheat, and thus weakened it for the winter season.

Investigations have demonstrated that the plow layer of black fallow, where it was overrun by the wheels of tractors and planters during the winter seeding, was considerably compressed. For instance, in 1952 20-cm and 30-cm plow layers in fallow land were compressed by 2.9 cm and 3.5 cm, respectively.

Investigations in areas plowed with and without the moldboard. After deep (30 cm) plowing of black fallow in the fall of 1955 with and without the moldboard, rods driven to different depths (10-20 replications) were left in the

Table 2

Changes in the vertical profile of individual parts of the plow layer under winter wheat in the fall of 1952

Depth, cm	Thickness of layers, in cm, at different times			
	Sept. 3	Sept. 30	Oct. 28	Changes during the period Sept. 3-Oct. 28
0—10	10.0	9.4	9.9	—0.1
10—20	10.0	10.6	10.7	+0.7
20—30	10.0	9.6	9.1	—0.9
30—34.5	4.5	5.3	5.5	+1.0

field over the winter. During the spring-summer period of 1956, the rods were removed from the soil before each cultivation of the fallow land and before manure was plowed in (to a depth of 15 cm). After each cultivation of the fallow, and also after planting winter wheat, the rods were replaced at the same sites. They were left until the harvest of the winter crops in June of 1957. This provided an opportunity to follow the shrinkage and expansion of the entire thickness of the plow layer and of its individual horizons from the time of plowing of the black fallow in the beginning of October, 1955, to the time of the winter crop harvest in 1957 (Table 3).

The data contained in Table 3 permit us to draw the following conclusions in regard to the condition of the field and its individual layers during the period from October 15, 1955, to July 3, 1957:

a) As compared to plowing without the mol board, moldboard plowing produce a more opened-up soil, i.e., the thickness of the plov layer increased (by 28% without the moldboar and 34% with the moldboard);

b) The following spring, three weeks after the fallow was harrowed, there was a shrinkage of the plow layer, most pronounced in the upper layer (0-10 cm);

c) When it was time to apply and plow in the manure (June 1) the over-all thickness of the plow layer remained unchanged;

Table 3

Changes in the vertical profile of plowland and its individual layers in black fallow and autumn plowland with moldboard and non-moldboard plowing (to a depth of 30 cm)

When determined	Date	Thickness of the plowland in cm, by layers									
		0-10		10—20		20—30		deeper than 30		total	
		mbd	no mbd.	mbd	no mbd.	mbd	no mbd.	mbd	no mbd.	mbd	no mbd.
After plowing	15.X 1955	10.0	10.0	10.0	10.0	10.0	10.0	10.2	8.4	40.2	38.4
In spring	11.V 1956	9.1	9.5	10.4	10.0	9.9	9.8	9.8	8.3	39.2	37.6
Before plowing in manure	1.VI »	9.0	9.4	10.6	10.1	9.8	9.6	9.9	8.5	39.3	37.6
		New installation of rods									
After planting winter crop	5.IX »	10.0	10.0	10.0	10.0	10.0	10.0	4.4	3.8	34.4	33.8
In fall on winter-crop field	11.X »	9.7	9.7	9.9	10.0	10.0	9.8	4.0	3.8	33.6	33.0
In spring, after harrowing	14.V 1957	8.2	7.7	9.6	10.2	10.2	9.9	4.1	4.2	32.1	32.0
Before harvesting winter crops	3.VII »	8.2	8.1	9.4	10.0	9.9	9.9	4.4	3.8	31.9	31.8

d) Immediately after the winter crop was nted, there was a considerable shrinkage of plow layer, more noticeable in the area wed with the moldboard;

e) A new shrinkage of the plow layer was ealed after the harrowing of the winter p with tractor-drawn harrows (three weeks) le in the area plowed without the moldboard vas limited to the 10-cm upper layer, in the ldboard area the next layer (10-20 cm) also s affected;

f) There were only insignificant changes in thickness of the plow layer during growth he winter crops in the spring-summer iod. In the case of black fallow plowed hout the moldboard, the soil layer at a th of 10-20 cm was more friable during s entire period. This fact is very important, ause in many cases it would be advisable to only deep stubble plowing on fields former- nder winter crops sown on fallow land wed without the moldboard. The deep bble plowing could be followed by grain ps, provided that the field had been cleaned weeds;

g) Between the time of black fallow plowing tober 1955) and the time of winter wheat vesting (July 3, 1957) the shrinkage of the w layer was larger (8.3 cm) in the area wed with the moldboard than in the areas wed without the moldboard (6.8 cm). To- rd the end of this period, the extra opened- soil in both area was not more than 18.-1.9 or 6% (instead of the 28-34% observed im- diately after plowing).

Changes in the height of individual vertical layers of fields and soil porosity.

The change in total soil porosity can be cal- ated from the height of the soil layer and its nges. This was suggested by Andrianov (1) assumed that a change in the total volume of soil (soil substance + spaces) involves only insignificant change in the volume of the solid se.

In determining the initial total porosity usual methods), the volume of absolutely soil is calculated. Knowing the capillary isture capacity and the particle density, ich varies within very narrow limits for h soil type in a given field, it is possible calculate on the basis of the volume of ab- utely dry soil the capillary and non-capil- y porosity. This method was suggested us (4,5) and described in other papers (2, 3).

Thus, when the particle density and capillary isture capacity of the soil in a given field are wn in advance, and after the total porosity been determined at the time of installing rods, it is possible to calculate from the nges in the height of individual layers the changes of the total — capillary and noncapillary porosity during a corresponding period. This method can be used directly in the field.

Conclusions

1) A method to determine the shrinkage and expansion of individual layers of the soil profile has been suggested.

2) By using this method on a leached chernozem at the field station of the Voronezh Agricultural Institute for a period of seven years the following facts have been established.

a) The processes which take place in individual parts of the vertical profile of a field can cause both: shrinkage or expansion of all layers, or shrinkage of some of them and expansion of others;

b) The various directions and forms of expansion and shrinkage over the entire thickness and in individual layers of the vertical profile of a field depend on the methods of tillage and planting and by the presence or absence of vegetation in the given area;

c) Determination of the extent of shrinkage and expansion of individual layers of fields assures a better choice of the equipment and depth of cultivation in the management of plowland and the planting of grain crops;

3) When the initial total porosity, the particle density, and the capillary porosity of the soil, as well as current changes in the height of individual layers are known, it is possible to calculate directly in the field the changes in the total capillary and noncapillary porosity for corresponding period of time.

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CHRONICLE

THE STALINGRAD SECTION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS DURING 1957-1958

. YE. PROSTAKOV

The Stalingrad Section of the All-Union ociety of Soil Scientists (VOP) was founded n January, 1957.

To render assistance in the study of soils of he region, the Section organized exhibits of soil naps, produced by the soils group of the Reional Land Utilization Department, and conultations on problems of classification and napping. To coordinate the soil research nd mapping efforts, the reproduction of soil naps compiled in the region was also organized.

During 1957-1958 ten papers on problems of oil classification, soil fertility, and the dyamics of soil processes were presented at neetings of the Section membership. Their urpose was to popularize and promote scienific information on soil science and agricultural hemistry. Two reports were read to the Deleates of the Congress of Soil Scientists; fifteen, t scientific conferences of the Stalingrad Agriultural Institute at which problems of soil cience were discussed; and one more — at an ut-of-town session of the All-Russian Lenin cademy of Agricultural Sciences (VASKhNIL) n Saratov.

The following works were published by the nembers of the Stalingrad Section: G. M. Tumin, 'Solonchak soils of the chestnut zone" — a popuar essay. A. S. Radov, 1) "Principles of working-out a fertilization system under the conditions f the Trans-Volga region;" 2) "Methods for the ffective utilization of mineral fertilizers;" 3) Experience in using fertilizers under the conitions of Stalingrad Region;" 4) "Following he example of the agricultural chemistry department in organizing and conducting laboratory-practical work;" 5) "Development of agricultural chemistry in the USSR during the last 40 years;" 6) "A collection of reports and speeches at the scientific-technical conference of the Stalingrad Agricultural Institute (SSKhI) in 1957;" 7) "The present state and development of agricultural chemistry in the People's Republic of Bulgaria;" 8) "Methodological guide for conducting laboratory-practical studies in agricultural chemistry;" 9) "Educational methods textbook" (second edition, with Assistant Pustovoy and Assistant Komissarov as co-authors). V. F. Shubin, 1) "Experimental utilization of virgin lands in Stalingrad region;" 2) "Method of T. S. Maltsev;" 3) "Criteria for an objective evaluation of 100 ha of arable land in socialist agriculture." S. G. Konurov, 1) "The influence of precursors upon the yield of spring wheat on light chestnut soil;" 2) "Comparative yield of grain on light chestnut soils."

The following articles were published in the book entitled, "Selskoye khozyaystvo Zavolzh'ya" (Agriculture of the Trans-Volga region): A. Radov, "A system of fertilizing;" V. Shubin, "System of farming and arrangement of crop rotation;" S. Konurov, "Field crops and their geographically classified varieties" (depending on soil conditions).

A number of works, concerned with the popularization and promotion of scientific knowledge on soil science and agricultural chemistry and prepared by members of the VOP during 1957-1958, are now in press.

ACTIVITY OF THE KAZAKH BRANCH OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS IN 1958

M. I. RUBINSHTEYN

The Kazakh Branch of the All-Union Society of Soil Scientists (VOP) has at present 120 members, who work in scientific schools and in the land-development parties of the Ministry of Agriculture. In 1958 the Kazakh Branch convened for the Second Republic-wide conference of soil scientists and four general meetings.

At the conference a lively exchange of opinions centered around a report delivered by P. G. Graborov entitled: "Results of a comparative study of the methods on particle-size analysis and on their application in the study of Kazakhstan soils." A meeting of the VOP members recommended that Graborov's method of pyrophosphoric particle-size analysis, designed for the carbonate soils of South Kazakhstan, should be used in laboratory investigations.

U. U. Uspanov's report "Natural conditions and soils of the Rumanian People's Republic," and V. M. Borovskiy's report, "Special features of the soil and the present state of agriculture in southeastern China," — were received with great interest.

The Presidium of the Branch discussed the tasks of Kazakhstan soil scientists in the light of N. S. Khrushchev's theses for the 21st CPSU Congress. As a result, an article was sent to the Republic newspaper on behalf of the members of the Society of soil scientists. It concerned the problem of organizing a soil service in Kazakhstan and certain measures for conserving and increasing soil fertility in the Republic.

In 1958 the Branch conducted a seven-day seminar on soil science and methods of soil investigations. It was attended by soil scientists of the Ministry of Agriculture.

Members of the Kazakhstan Branch took an active part in working out operational farming plans for the kolkhozes and sovkhozes of the Republic. Soil descriptions were written and the regional division of soils for agriculturel purposes was carried out in each of 16 regions. Material pertaining to operational plans for farming were published in 1958.

Members of the Branch delivered more than 20 lectures during this period on methods of farming in relation to soil conditions.

ACTIVITY OF THE BASHKIR SECTION OF THE ALL-UNION SOCIETY OF SOIL SCIENTISTS IN 1958

. N. TAYCHINOV

The four enlarged sessions of the Council nd Presidium of the Section discussed probems pertaining to the work of the Presidium nd to the progress made by members in carryng out their individual assignments.

One of the general meetings was dedicated o the problems of classification (information eports were delivered by S. N. Taychinov, M. M. Turovtsev, M. S. Shigayev, A. D. Blinova, nd others). It also discussed the accomplishnents and plans of the soil parties.

A new proposal, calling for a more accurate ystem of natural and agricultural soil districtng of the Bashkir Republic, was discussed and dopted at an inter-departmental meeting, which was attended by representatives of cientifical-research institutions, the Bashkir Ministry of Agriculture, the inspection board f the Gossortset (State Seed-Selection Network), nd others.

S. N. Taychinov and M. M. Turtsev reported o the Council on the results of the Moscow conerence and on recommendations of the Republicwide congress of soil scientists concerning cerain ammendments to the proposed new system f agricultural soil districting of Bashkiriya.

G. V. Vakhrushev's report, entitled "Agriultural minerals in the service of the agriculure of Bashkiriya," and Yu. A. Usmanov's nformation report, entitled "Prospects for hosphating and liming of the soils of Bashkirya," were delivered at scientific sessions.

During this year members of the Section devered more than 30 lectures and several reorts on topical agricultural problems in rural istricts, kolkhozes, and sovkhozes. Twentyve articles were published in Union-wide and egional newspapers and magazines.

A writing team, headed by an editor, S. N. Taychinov, prepared and submitted for publication a collection of papers, entitled: "Natural resources and certain problems of the agriculture of Bashkiriya." Its publication is timed to coincide with the 40th Anniversary of the Bashkir Autonomous Republic.

Members of the Council and the Presidium visited rural districts to give assistance on methods to offer advice, and to deliver lectures. A joint effort of a group of soil scientists from the Bashkir Agricultural Institute, the Agricultural Research Institute, and the Land-Development Administration worked out a scheme for preparation of a description and detailed soil maps covering the Republic's kolkhozes and sovkhozes.

The Bashkir Section of the VOP prepared and submitted for publication the first issue of its Bulletin. Its purpose is to give more effective production-level assistance and to popularize agricultural soil science. The second issue of the Bulletin is being prepared.

There are still many deficiencies in the work of the Section. Not all members participate actively in various projects; visits to rural districts are few; relations with agricultural chemistry laboratories and with leading agricultural workers are insufficient, membership of the Section is not growing (there are 35 members), etc.

In connection with the far-reaching tasks of agricultural development under the seven-year plan, the Council and the Presidium of the Bashkir Section are taking measures to improve their work and to establish contacts at the working level.

OBITUARY

ALEKSEY NIKANOROVICH SOKOLOVSKIY (1884-1959)

I. V. TYURIN, A. V. SOKOLOV, V. P. BUSHINSKIY, S. S. SOBOLEV, V. A. FRANTSESSON,
N. P. KARPINSKIY, N. K. BALYABO, A. M. GRINCHENKO, N. K. KRUPSKIY

Academician Aleksey Nikanorovich Sokolovskiy died suddenly at the age of 75 on April 25, 1959. He was a member of the VASKhNIL, the Ukrainian Academy of Sciences, the Ukrainian Academy of Agricultural Sciences; and Director of the Kharkov Institute named after V. V. Dokuchayev. He had the titles of Meritorious Scientific Worker of the Ukraine and of Doctor of Agricultural and Geological-Mineralogical Sciences.

Sokolovskiy was born on March 14, 1884 in the small town of Velikaya Buromka, Zolotonosh District, Poltava Province. After finishing high school in Poltava in 1902, he entered the Kiev University, where he studied geology under Academician N. I. Andrusov. Upon graduation, he went to the Moscow Agricultural Institute (Timiryazyev Agricultural Academy) (TSKhA) where he studied in the laboratories of D. N. Pryanishnikov and V. R. Vil'yams. After finishing his course of studies, he became a research assistant and instructor in soil science at the TSKhA Institute under V. R. Vil'yams (1910-1924). In 1922 he was appointed to a professorship at the Moscow Geodetic Institute, and from 1924 until his death he was in charge of the soil science department of the Kharkov Agricultural Institute named after V. V. Dokuchayev (formerly the Novo-Aleksandrovskiy Institute).

Sokolovskiy was one of the outstanding Soviet Soil scientists and a pioneer of the modern teaching on genesis and chemical soil reclamation by means of liming and the addition of gypsum and phosphorite. He wrote more than 100 papers, including early classics (1914-1919) pertaining to the study of soil colloids, "active" clay, soil calcium saturation and soil structure. These early works of his provided a new approach to problems of genesis and radical soil improvement. While part of the gold reserves of soil science, they also served as a basis for the emergence of the technical colloid chemistry of soil materials, which opened a new chapter in the development of the building industry. Sokolovskiy's geochemical research provided a new interpretation of the genesis of saline soils and of the significance of salt domes in salinization and desalinization. It also contributed to the modern concept of the interrelations between natural phenomena and the geography of saline soils.

Sokolovskiy's theoretical research was characterized by its practical applicability. Thus, his works pertaining to the liming of soils; reclamation of solonetz soils in the southern Ukraine and middle Denpr region; promotion of the solonetzing of irrigation ditches, the bottoms of water reservoirs and manure ponds to control seepage; the depth of plowing and types of plow layers; reasons for winter crop failures; crop rotation; and war-time erosion; all are excellent examples of the use of serious theory for the solution of practical agricultural problems.

Widely known is Sokolovskiy's research wor in the following fields: genetic soil classification, taking into account not only the content of adsorbed ions and the distribution of colloids in the soil profile, but also the nature of the colloidal complex and of the structure-forming agents; soil cartography of the Ukraine; history of soil science and agronomy; determination of genetic soil horizons and their rational nomenclature; differential dispersion analysis of humus; the origin of loess; and others.

In addition to being a major scientist, Sokol skiy was also an outstanding teacher who traine generations of agronomists, foresters, and soi scientists. He was the author of the best, and the earliest, textbooks on agricultural soil science.

Sokolovskiy played a major role as an administrator. Under his leadership the Kharko Agricultural Institute was rebuilt after the Gre Patriotic War, and on his initiative the first Ukrainian soil institute was founded. Until his death, Sokolovskiy was continuously in charge of these two institutions.

n recent years he had been one of the or- izers of the campaign to produce soil maps cartograms of the Ukrainian kolkhozes and khozes.

okolovskiy was also active in civic affairs. was a member of the All-Union Peace Com- tee, a Deputy in the Kharkov Regional Soviet, irman of the Regional Society for Promotion olitical and Scientific Knowledge, and an orary Member of the All-Union Society of Scientists.

n recognition of his outstanding services, Soviet Government awarded Sokolovskiy ee Lenin Medals, three Labor Red Banner dals and one Badge of Merit.

okolovskiy'a name is well known in Soviet icultural scientific circles. His contribu- s in the fields of science and training of entific and production specialists were great. will be long remembered as a leading pro- tor of Soviet science.

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